SPADE-2: THE SOIL PROFILE ANALYTICAL DATABASE FOR EUROPE

VERSION 1.0

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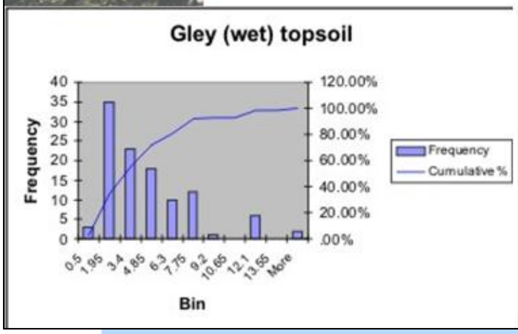

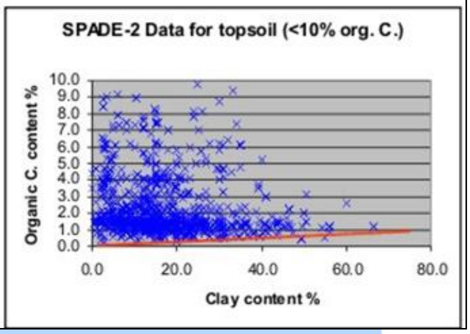

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SPADE-2: THE SOIL PROFILE ANALYTICAL DATABASE FOR EUROPE

VERSION 1.0

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PREFACE

This document provides information on the derivation and use of version 1.0 of the digital Soil Profile Analytical Database for Europe, SPADE-2, derived on behalf of the European Commission and the European Crop Protection Association.

The document describes the background to development of the database, the method of its derivation and the validation procedures carried out. It also provides some guidance on use of SPADE-2 in association with the 1:1,000,000 scale Soil Geographical Database of Europe.

The project was co-ordinated by the National Soil Resources Institute of Cranfield University and contact details for the project manager are as follows:

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DISCLAIMER

Users who identify any obvious errors in the database should notify the European Soil Bureau Secretariat, Land Management Unit, Institute for Environment & Sustainability, TP 280, Joint Research Centre (JRC), Ispra (VA), 21020 Italy.

SUMMARY

1. The European Soil Database – ESDB – (version 1.0) has been developed over the last two decades through the efforts of the European Soil Bureau Network.
2. The database has four main components: the 1:1,000,000 Soil Geographical Database of Europe (SGDBE v. 3.2.8.0), the European Soil Profile Analytical database, SPADE-1 (v. 2.1.0.0), the European Pedo-Transfer Rules database (v. 2.0), The HYPRES pedo-transfer functions (v.1.0).
3. SPADE-1 was developed to characterise each soil type or Soil Typrological Unit (STU) defined in the database, according to a range of properties that are important for agricultural and environmental interpretation and modelling.
4. However, because of the large range of data required and the limited financial resources available, it was proposed to develop the database in different stages (levels).
5. The SPADE-1 database comprises two types of data characterising soil profiles: the 'Estimated Profile' and the 'Measured Profile' data files. Only the 'Estimated Profile' data can be used for European level modelling purposes because the measured soil profile data are too sparse.
6. The SPADE-1 database contains 447 Estimated Profiles, the SGDBE contains 3164 STUs representing the EU-15 countries covered. In addition, of the 447 SPADE-1 Estimated Profiles, only 240 are linked to STUs (8% of the total number of STUs).
7. Furthermore, there are no profile data for 3 countries and, of the 1206 STUs with a designated dominant land use of 'Arable', only 78 (6%) are linked to a SPADE-1 profile. Thus it is clear that the SPADE-1 data has serious limitations for use in European level modelling
8. As a result of these limitations the European Crop Protection Association, supported by the European Soil Bureau of the European Commission's Joint Research Centre, have sponsored the compilation of a second version (SPADE-2) of the profile database for use with the Soil Geographical Database of Europe.
9. The overall objective is to provide sufficient soil property data to support higher tier modelling of pesticide fate at a European level and the main aim was to expand the 'estimated' soil profile database to include 'primary soil properties' for all Soil Typological Units in the SGDBE v 3.2.8.0 and for both the designated dominant and secondary land uses for all the European Union Member States (as of November 2002). Primary Soil Properties are: clay%, silt%, fine sand%, medium sand%, coarse sand%, organic carbon%, pH, bulk density.
10. Data were supplied by the designated national contacts for Belgium & Luxembourg, Denmark, England & Wales, Finland, Germany, Italy, Netherlands, Portugal and Scotland. Designated national contacts from other Member States either declined to supply data or could not provide the requested data within the project time-frame.
11. Data supplied by each country were based on the national data archives and, for some parameters, particularly particle-size distribution, the analytical techniques used varied slightly from country to country.
12. The raw data supplied by national data providers has thus been harmonised and validated to provide a single data file (SPADE_2.dbf) that can be easily used in conjunction with the SGDBE.
13. Harmonisation of particle-size data was carried out using a monotonic cubic spline interpolation procedure.
14. Validation analyses have been carried out to ensure that any problems related to the harmonisation procedure were identified and corrected and that the range and population distributions of all parameters were consistent with expected patterns and ranges. Unusual outliers within parameter data sets were identified and, if necessary, corrected.
15. The completed SPADE-2 database, v. 1.0 comprises two separate sets of data files: SPADE_2_raw.xls; SPADE_2.dbf.
16. SPADE_2_raw.xls is a Microsoft EXCEL file comprising a set of worksheets each containing the raw data supplied by each national data provider. These data are included for completeness and future reference only. It is not intended that they be used to link with the spatial data held in

the Soil Geographical Database of Europe (SGDBE).

17. SPADE_2.dbf is the harmonised data file for use with the SGDBE. It covers all of Belgium, Denmark, England, Finland, Germany, Italy, Luxembourg, Netherlands, Portugal, Scotland and Wales. The file comprises 1897 complete soil profiles directly linked to 1077 STUs (35% of all STUs for the EU-15 countries) and fully characterising 313 SMUs of the SGDBE. Of the 1897 SPADE-2 profiles included, 1288 have an agricultural land use and the remainder represent a variety of non-agricultural land uses.
18. SPADE_2.dbf is in dBASE-IV format and can also be viewed using Microsoft Excel. However for spatial representation or analysis, the SPADE-2 data must be linked to the geometric component of the ESDB, the SGDBE.
19. Although the SPADE_2 database represents a comprehensive expansion and increase in utility of the soil property data in SPADE-1 (v.2.1.0.0), when working at a European level there remain some significant gaps.
20. It is therefore recommended that continuing efforts are made to obtain and harmonise data from countries that did not supply data for this version of SPADE-2.
21. Finally, it is recommended that the database and methods used to derive it be extended to include soil property data from the New Member States of the Enlarged EU, the former EFTA nations (Norway & Switzerland), Candidate Countries (Bulgaria, Croatia & Romania), and the Neighbouring Countries of the Western Balkans.

INTRODUCTION

The European Soil Database (SDBE version 1.0) has been developed over the last two decades through the efforts of the European Soil Bureau Network and its predecessors, co-ordinated since 1990 through the Secretariat of the European Soil Bureau, Institute of Environment and Sustainability, European Commission Joint Research Centre, Ispra, Italy.

The database has four main components:

- The 1:1,000,000 Soil Geographic Database of Europe (SGDBE v. 3.2.8.0
- The European Soil Profile Analytical database, SPADE-1 (v 2.1.0.0).
- The European Pedo-Transfer Rules database 2.0.
- The HYPRES pedo-transfer functions v 1.0.

Soil Geographic Database of Europe SGDBE

This database can be used both with in ArcView™ (v 3.2, 8.3) and with ArcGIS™ (v 8.2, 8.3). The database is a digital version of the 1:1,000,000 Soil Map of Europe (CEC 1985), which was compiled in the 1970's but considerably updated in the 1990s through the efforts of the European Soil Bureau Network, under institutional funding of the Joint Research Centre. The database has geometric and semantic components, soil information being presented in the form of Soil Map Units (SMUs) with each polygon (geometric or spatial) unit on the map being assigned to a single SMU. Each SMU comprises a number of soil types or Soil Typological Units (STU) which are associated together within the SMU landscape but cannot be separated spatially at the 1:1,000,000 map scale.

The digital data cover all the Member States (25) of the Enlarged EU, former EFTA nations (Norway & Switzerland), Candidate Countries (Bulgaria, Croatia & Romania), and Neighbouring Countries of the Western Balkans. Figure 1 shows a representation of the database depicting the major soil group according to the World Reference Base for Soil Resources (FAO, 1998).

Included within the database are four data tables in DBase (.dbf) format:

- SOIL.PAT – Specifies the perimeter length, area, etc. of each polygon.
- SMU – Specifies the area and number of polygons for each SMU.
- STU.ORG – Specifies the code and percentage cover of each STU in each SMU.
- STU – Defines a range of attributes for each STU.

The SPADE-1 database comprises soil property data for each significantly different soil layer in a range of representative soil profiles within Europe.

Soil Profile Analytical Database for Europe: SPADE-1

The objective of developing a Soil Profile Analytical Database for Europe (SPADE), Level 1 (version 2.1.0.0) to form an integral component of the European Soil database is to characterise each soil type (STU) defined in the database according to a range of properties that are important for agricultural and environmental interpretation and modelling. The compilation of SPADE was first discussed at a meeting with the Directorate-General Agriculture of the European Commission (then DG VI) in the autumn of 1986, following publication of the Soil Map of Europe at scale 1:1,000,000 (CEC, 1985).

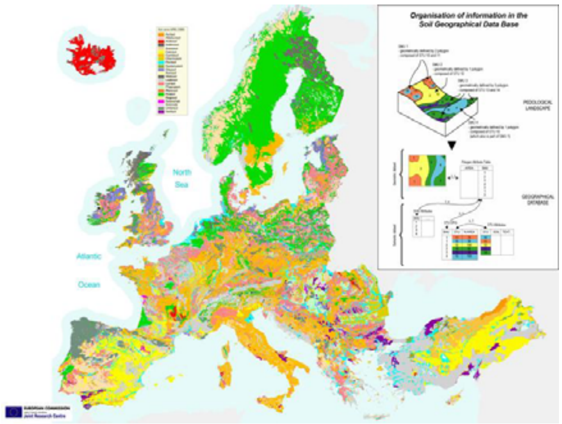


Figure 1. European Soil Database, showing the data structure

Madsen (1991) formally outlined the principles of such a profile database at a meeting of the Heads of Soil Survey in Europe, held at Cranfield University Silsoe Campus, December 1989. The Soil Map of Europe had been digitised in the late 1980s under the programme Coordination of Information on the Environment (CORINE) of the European

Commission (Platou *et al*., 1989). The original intention for the SPADE database was to collect representative soil profile data for all the main soil types distinguished on the published Soil Map of Europe. This would provide additional information, on soil properties with European coverage in a standard form, to enhance the legend of the original map.

However, because of the large range of data required and the limited financial resources available, it was proposed to develop the database in different stages (levels). The number of soil types to be computerized would vary according to the time available and the funding forthcoming. It was decided to start by compiling data for a few important and extensive soil types (Level 1) and then later follow up with a second (Level 2), third (Level 3) and even fourth level of detail (Level 4).

The initial contract for a restricted compilation of the SPADE-1 database was signed with JRC (MARS Project), to focus on Level 1, a single representative soil profile for the dominant STU in the most important SMUs in Member States. The work began in 1992 with the design of standard forms for capturing profile data for the EU-12 Member States (Madsen & Jones, 1995a, b). For compiling the SPADE-1 database at level 1, two different formats (Proformas) were defined (Breuning-Madsen & Jones, 1995):

- Proforma I (estimated data): for capture of profile data recognised as truly representative of specific soil types, but not geo-referenced to any particular location. National experts were requested to provide the data preferably from measurements or, where no measured data existed, estimated data according to the specified format and where data had been determined by analytical methods that could not be harmonised. Some problems of data confidentiality were avoided because the data could be linked to spatial units (map units) only though soil type and not to any particular place.
- Proforma II (measured data): was designed to capture measured data from georeferenced sample points, for which the soil had been examined and analysed. The analytical methods applied are recorded, but not necessarily harmonized between samples. It was accepted that some of these data might not be truly representative of soil types shown on the map and some data might be missing for some parameters.

HYPRES database

The HYPRES database comprises a set of pedo-transfer functions (PTF) for deriving soil hydraulic characteristics from basic soil property data. The functions are derived from measured soil hydraulic properties collected during the HYPRES network project (Wösten *et al* 1998) funded under the European Commission's FP5 Capability and Mobility (DGXII) programme. Data from 4030 soil horizons were collated, comprising 1136 soil horizons with measured water retention and hydraulic conductivity and 2894 horizons with measured water retention only. The data were analysed statistically to derive two sets of pedo-transfer functions:

- A set of 11 'class functions' related to each of the 5 broad mineral texture classes (e.g. TEXT1, TEXT2) and the organic texture class used in the STU attribute tables in the SGDBE v. 3.2.8.0. PTFs are derived for both topsoils and subsoils in each mineral texture class but no such distinction is made for the organic texture. For each of the 11 classes, values are given for the Mualem-van Genuchten hydraulic model parameters as well as derived moisture contents and conductivities at 14 pressure heads.
- A set of 'continuous functions' which derive the Mualem-van Genuchten hydraulic model parameters from basic data on clay%, silt% (0.002 – 0.05 mm), bulk density and organic matter (see van Genuchten & Leij, 1992).

The objective of deriving the two sets of functions is to enable hydraulic characteristics to be derived for STU in the SGDBE either using the broad texture class attributes in the STU data table or using the soil property data available in the SPADE-1 database.

The need for more comprehensive soil property data

As described above, the SPADE-1 database comprises two types of data characterising soil profiles: the 'Estimated Profile' and the 'Measured Profile' data files. Only the former is intended for use to support modelling, it specifically represents the STU components of soil map units (SMU) included in the Soil Geographic Database for Europe. Two problems exist in using the Estimated Profile data for modelling purposes.

Firstly, the profile data supplied were not always linked to an SMU or one of its component STUs. It was therefore decided to build a Profile-to-STU link table that indicates, wherever possible, the STU to which each set of estimated profile data is correlated. Two types of links are identified depending on their order of priority and reliability:

1. An EXPLICIT link (indicated by the number 1 in the LINK_TYPE file). If the author of a profile explicitly gave a list of one or more SMUs to which the profile applies, then the profile was linked to the dominant soil type in all those SMUs for that country, providing that STU attributes of COUNTRY, SOIL & TEXT1 matched. Such explicit links have a high priority over other link types and are highly reliable.

2. An IMPLICIT link indicated by the number 2 in the LINK_TYPE file). If the author of a profile did not indicate any SMU to which the profile applies, then the profile was linked to all dominant soil types for that country that matched the linking STU attributes of COUNTRY, SOIL & TEXT1. Such implicit links have a lower priority than explicit ones and are less reliable.

Even after this process had been carried out, a number of the estimated soil profiles could not be assigned to an STU using the explicit or implicit linkage.

Secondly, although a total of 447 estimated profile data sets were supplied for the 15 Member States that comprised the EU at that time, this was a very small number of data sets to represent the 3164 STU that were identified in these countries. In addition, each estimated profile only represented a single (normally the dominant) land use and for some countries no specific land use was identified.

The overall situation is quantified in Tables 1 and 2. These show that, of the 3164 STU in the EU-15 countries detailed here, only 8% (240 profiles) have an explicit or implicit link to the estimated profile data in SPADE-1. In addition, 3 countries have no profile data at all and, of the 1206 STU with a designated dominant land use of 'Arable', only 78 (6%) are linked to a SPADE-1 profile.

Table 1. SPADE-1 Estimated profiles and links to STU on a land use basis

Country	Total STUs	Total profiles	With explicit link to STU	With implicit link to STU
Austria	30	0	0	0
Belgium	114	42	0	0
Denmark	71	11	0	7
Eire	100	30	0	21
Finland	14	0	0	0
France	772	118	97	2
Germany	489	60	0	0
Greece	119	11	0	4
Italy	168	21	6	0
Luxem-bourg	25	13	3	0
Nether-lands	49	21	3	0
Portugal	188	21	0	17
Spain	206	44	0	34
Sweden	356	0	0	0
UK	463	55	23	23
Totals	**3164**	**447**	**132**	**108**

From this analysis it is clear that, when applying models at the European level using the Soil Geographical Database of Europe (SGDBE), the SPADE-1 'Estimated Profile' data has serious limitations.

Table 2. Characteristics of the primary soil property data supplied by the national data providers for SPADE-1.

Land Use	Total STU (dominant land use)	Total SPADE-1 profiles	With an explicit link to STU	With an implicit link to STU
No specified land use	23	14	3	0
'Agriculture'	0	55	0	16
Arable	1206	122	54	24
Grassland	547	94	19	31
Extensive pasture	114	5	1	3
Horticulture	15	4	3	0
Vineyards	15	8	4	2
Orchards	5	3	2	1
Industrial Crops	5	0	0	0
Rice	4	0	0	0
Cotton	3	2	0	2
Olives	17	0	0	0
'Ley lands'	0	1	1	0
Non agricultural	1206	139	45	29
Totals	**3164**	**447**	**132**	**108**

SPADE-2 project objectives

As a result of the limitations of the SPADE-1 profile data for use in modelling at the European level, the European Crop Protection Association (ECPA), supported by the European Soil Bureau of the European Commission Joint Research Centre have sponsored the collation of a second profile database (SPADE-2) for use with the SGDBE. The overall objective was to provide sufficient soil property data to support higher tier modelling of pesticide fate at the European level.

The main aim of the SPADE-2 project is to expand the 'estimated' soil profile database to include 'primary soil properties' for all Soil Typological Units in the SGDBE v 3.2.8 and for both the designated dominant and secondary land uses (USE1 and USE2 in the stu.dbf file) for all the EU Member States as of November 2002.

Primary Soil Properties are:
clay%, silt%, fine sand%, medium sand%, coarse sand%, organic carbon%, pH, bulk density.

DERIVATION AND VALIDATION OF SOIL PROPERTY DATA

Derivation of the soil property data was achieved through the European Soil Bureau Network (Montanarella *et al*., 2005).

The designated Network data providers from Austria, Belgium & Luxembourg, Denmark, England Wales & Northern Ireland, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Portugal, Scotland, Spain and Sweden were contacted about participation. There was a negative response from Austria and no reply was ever received from Greece. Protocols for data generation and formal sub-contracts for provision of the data were then sent to the remaining National data providers. During subsequent negotiation, it was established that the specified data could not be supplied for France, Spain, Sweden and Ireland within a feasible project time-scale. All other countries: Belgium & Luxembourg, Denmark, England Wales & Northern Ireland, Finland, Germany, Italy, Netherlands, Portugal and Scotland, supplied complete data sets by March 2004.

Data derivation protocol

The long-term objective of the SPADE-2 project is to provide, for each country in the European Union, a land use-specific data set of soil primary properties relevant to each soil typological unit (STU) of each soil map unit (SMU) included in the 1:1,000,000 Soil Geographical Database for Europe, v. 3.2.8

Soil Primary Properties

The soil properties required for each STU are as follows:

Soil horizon data
Horizon nomenclature symbol according to the guidelines for soil description of FAO (1990),
Upper depth (cm),
Lower depth (cm).

Particle-size fractions: (as a % of the less than 2mm fraction), clay, silt, content of at least 3 sand fractions (fine, medium, coarse).
The exact definition of the equivalent spherical diameter (esd) of each fraction should be specified by the data provider (e.g. clay fraction <0.002 mm, silt fraction 0.002 to 0.05 mm, fine sand fraction 0.05 to 0.2 mm, etc.). The exact method of determination should be specified by the data provider.
Stone content (as a % of the total solid fraction).

pH in water (1:2.5).

Organic Carbon content (%).
Preferably, based on the Walkley & Black (1934) analytical procedure (see also Tinsley 1950). If not, the exact method of analysis to be specified by the data provider.

Dry Bulk Density ($g.cm^{-3}$).
Exact method of determination to be specified by the data provider.

Method of derivation of Soil Properties

The data provider was supplied with two Microsoft Excel spreadsheets:

Spreadsheet 1. Comprises a list of each STU in each country, the SMU in which it occurs and the existing associated attributes for the STU (e.g. soil type, dominant land use, secondary land use, dominant parent material, secondary parent material, etc.).

Spreadsheet 2. Comprises a list of each STU, the specified dominant land use and secondary land use of each STU, the horizon sequence for each land use-specific STU and, for each of these, a column for each of the soil primary properties that are required for the database. For the particle-size fractions, pH and organic carbon content, columns for the mean value and standard deviation are included. Standard deviations are NOT required for horizon depths or bulk density.

Procedure.
The data provider was requested to complete Spreadsheet 2 with all the soil primary property values and, where relevant, the standard deviation values. The data must be relevant to the specified land use of the STU (i.e. two data sets are required for each STU, specific to the dominant and secondary land use. However, only one data set is required if there is no specified secondary land use or if the dominant and secondary land uses are the same). The attribute data supplied in spreadsheet 1 provides some general pedological, environmental and soil profile characteristics specific to each STU and should be taken into account when driving the soil primary property data.

The following stepped approach is recommended for deriving land use-specific STU primary property data for each soil horizon:

1. Create the land use-specific horizon sequence and depths for the STU, taking into account the attribute data in Spreadsheet 1. Wherever possible the soil profile should extend to 1.5m depth or to rock whichever is shallower. Rock horizons should be indicated by the symbol R (‘hard’ rock) or Cr (‘soft’ rock) in the horizon symbol column and a ‘-7’ in all the other data columns
2. Complete the remaining soil property data using the following procedure:
3. If at least 5 measured data points are available for the land use-specific STU:
   - Calculate the mean value and the standard deviation.

- Use expert judgement to assess whether these values are relevant for the land use-specific STU.
- If you consider the values to be representative, insert them into the 'mean value' and 'standard deviation' columns.
- If you consider them to be unrepresentative, use expert judgement to adjust the calculated mean value to a more representative value and put '-8' in the standard deviation column.

4. If less than 5 measured data points are available for the land use-specific STU:
   - Calculate the mean value.
   - Use expert judgement to assess whether this value is relevant for the land use-specific STU.
   - If you consider the value to be representative, insert it into the 'mean value' column and put '-1' into the standard deviation column.
   - If you consider the value to be unrepresentative, use expert judgement to adjust it to a more representative value and put '-8
   - ' in the standard deviation column.
5. If no measured data points are available for the land use-specific STU:
   - Use expert judgement to assess a relevant mean value for the property and put '-9' in the standard deviation column.

Within the completed database therefore:
'-1' indicates 'Insufficient data to derive a relevant standard deviation.'
'-7' indicates 'Rock horizon.'
'-8' indicates 'mean value based on expert judgement using a limited amount of measured data.'
'-9' indicates 'mean value based on expert judgement only.'

Harmonisation of data supplied

The principal problem with deriving a consistent soil property data set for the European Union is that the analytical techniques used to create the soil data archive available to each National data supplier are often slightly different. When bringing such data together at the European level, these differences need to be recognised and, where possible, the data harmonised. Table 3 shows the characteristics of the data supplied by each national provider. It indicates a need for harmonisation of the particle-size data but suggests that the organic carbon data should be consistent as should be the pH data apart from that from the Netherlands. The following harmonisation procedure was carried out:

Particle-size distribution

All data was first checked for errors to ensure that the sum of all the fractions was between 99 and 101%. Any major errors were referred to the data suppliers and corrected. An automated curve fitting routine was then used to harmonise the particle size data points at 0.002, 0.05, 0.1, 0.2, 0.5, 2 mm esd.

Various constant form curves were fitted to the data. A logistic curve gave the best overall fit but still showed that significant numbers of individual data sets give a statistically unacceptable fit. It was therefore considered unlikely that any constant-form curve would be acceptable and a revised procedure was developed:

For each data set, the equivalent spherical diameter (esd) data was transformed to a Log Phi value.

$$\Phi = -\log_2 d = -\{\log_{10} d / \log_{10} 2\}$$

where d is the equivalent spherical diameter.

A monotonic cubic spline procedure was then used to interpolate between the transformed data points to derive values at the desired standard esd intervals. The derived data was then again checked for errors to ensure that $99 < \Sigma(\text{fractions}) < 101$. Any minor discrepancies corrected by reference to the original data.

The interpolation procedure could not be applied to the data for Scotland because within the SPADE-2 database, the individual sand fractions for STUs unique to Scotland were not provided. Only the total sand contents (between 0.05 and 2 mm esd) were supplied thus there were insufficient data points to fit a curve.

Organic carbon

No harmonisation of this data was considered necessary.

pH

All countries supplied pH values measured in a 1:2.5 mixture of soil and water, except for the Netherlands where pH was measured in a solution of 0.1 M KCl. In the report on FOCUS Groundwater models (FOCUS, 2000), it has been suggested that the following equation can be used for conversion:

$$\text{pH (0.1M KCL)} = 0.7\ [\text{pH (1:2.5 soil:}H_2O)]$$

However, because of the uncertainty related to this factor, it was decided not to convert the pH data for the Netherlands but rather to incorporate them into the database in a separate field. This will ensure that users are aware that the pH data for the Netherlands is different to that for all other countries but will allow use of a conversion factor for pan-European investigations. The SPADE-2 database thus has two field containing pH data: one for pH in a 1:2.5 soil:water ratio and one for pH in 0.1 M KCl.

Validation of the derived property data

In order to ensure that the data supplied are consistent and that the harmonisation procedure used to derive the standard particle-size data sets had been applied correctly, a validation check was carried out. Organic carbon content, pH and bulk density data sets were checked against soil type land use combinations and population distributions plotted to identify ‘outliers’. Statistical comparison of the interpolated particle-size fractions with the original (corrected) fractions provided by each national data supplier was carried out to assess the accuracy of the interpolation procedure.

Particle-size distribution

Figures 2 to 5 show specific interpolated data plotted against original data. For the majority of the data supplied, a very good fit was achieved and Figure 2 illustrates this for an STU in Portugal. In contrast, Figures 3 to 5 illustrate the type of problems where the interpolated data fit less well. Differences between the fitted and original data for silt and finer sand fractions can be seen in Figure 3 but such minor errors are to be expected in any fitting procedure. Of more concern are problems arising where the particle-size distribution is strongly skewed towards a single fraction such as clay or sand.

For example, in Figure 4, the clayey particle-size data set has a cumulative particle-size percentage that exceeds 100%. In Figure 5, the sandy particle-size data set has fitted values that are negative for clay-sized material and the cumulative particle-size percentage again exceeds 100%. All cases where the interpolated data gave negative values or a cumulative percentage falling outside the range 99-101 these errors were corrected manually by reference to the original data supplied.

Statistical analysis of all the interpolated data that did not have negative values or a cumulative percentage outside the range 99-101 was then carried out to evaluate the ‘goodness of fit’ between the interpolated data points and the data originally supplied. Tables 4 and 5 show the model efficiency (ME) for the fitted data. The model efficiency rating (Melacini *et al.*, 1995) can range between very large negative values and +1. Any negative value indicates an unacceptable fit whereas values in excess of 0.6 indicate a good fit and values of 1 an almost perfect fit.

For the total data set the interpolated values show a very good fit to the original data with all size fractions having model efficiencies greater than 0.9 and most greater than 0.95. Broken down on a national basis, virtually all of the interpolated values show a very good fit but model efficiencies of less than 0.6 are associated with the medium sand size fraction for Belgium & Luxembourg and Italy.

This analysis indicates that the interpolation routine used to harmonise the particle-size data gives very reliable results for the main size fractions of clay (<0.002 mm), silt (0.002 to 0.05 mm) and total sand (0.05 to 2 mm). Values for individual sand-size fractions are likely to be slightly less accurate but should still be acceptable. Model efficiencies suggest that least reliance should be placed on the individual sand-size fractions for England and Wales and for the >0.2 mm fractions for Belgium & Luxembourg and Italy.

Table 3. Characteristics of the primary soil property data supplied by the national data providers.

Country	**Size range (mm) for particle-size fraction**					**Org. C. Method**	**pH solution**
	Clay	**Silt**	**Sand 1**	**Sand 2**	**Sand 3**		
Belgium & Luxembourg	0.002	0.05	0.2	0.5	2	WB [1]	H_2O
Denmark	0.002	0.05	0.2	Not used	2	WB [1]	H_2O
England, Wales & N. Ireland	0.002	0.06	0.2	Not used	2	WB [1]/ Dr C [2]	H_2O
Finland	0.002	0.06	0.2	0.6	2	WB [1]/ Dr C [2]	H_2O
Germany	0.002	0.06	0.2	0.6	2	WB [1]/ Dr C [2]	H_2O
Italy	0.002	0.05	0.25	0.5	2	WB [1]	H_2O
Netherlands	0.002	0.05	0.105	0.21	2	WB [1]	KCl
Portugal	0.002	0.05	0.2	Not used	2	WB [1]	H_2O
Scotland	0.002	0.05	Not used	Not used	2	CHN [3]	H_2O

[1] Walkley & Black (1934) method; [2] Dry combustion (loss on ignition) – peat soils only;
[3] CHN Analyzer

Table 4. Model efficiency of the interpolated particle-size data for clay, silt, total & fine sand fractions for all data sets excluding those manually corrected.

Country	**n**	**Clay**		**Silt**		**total sand**		**fine sand**	
		mean	**ME**	**mean**	**ME**	**mean**	**ME**	**mean**	**ME**
Belgium & Luxembourg	599	21.7	0.9997	56.5	0.9996	21.8	0.9994	16.8	0.9988
Denmark	264	11.9	0.9986	20.7	0.9966	67.4	0.9996	26	0.9977
England & Wales	1902	25.8	0.9893	36.2	0.8681	37.9	0.9753	17.7	0.7153
Finland	197	20.1	0.9997	33.6	0.9903	46.4	0.9995	22	0.9985
Germany	227	38.6	0.9978	18.1	0.9653	42.8	0.9975	20.2	0.9768
Italy	360	30.2	1.0000	45.0	1.0000	24.7	0.9992	14.1	0.9952
Netherlands	212	19	0.9996	36.0	0.9950	44.9	0.9985	21.1	0.974
Portugal	890	21.6	0.9997	17.1	0.996	61.3	0.9997	28.9	0.9990
All countries	**4651**	**24.2**	**0.9956**	**34.0**	**0.9651**	**41.8**	**0.9914**	**20**	**0.9064**

Table 5. Model efficiency of the interpolated particle-size data for medium & coarse sand fractions for all data sets excluding those manually corrected.

Country	n	medium sand		coarse sand		med+coarse sand	
		mean	ME	mean	ME	mean	ME
Belgium & Luxembourg	599	2.5	0.5686	2.4	0.8382		
Denmark	264					41.2	1.0000
England & Wales	1902					20.2	0.9769
Finland	197	13.7	0.9673	10.6	0.9657		
Germany	227	11.4	0.9915	11.2	0.9925		
Italy	360	2.4	0.5680	8.2	0.9084		
Netherlands	212					23.8	0.9959
Portugal	890					32.3	1.0000
All countries		**5.7**	**0.959**	**7.13**	**0.9778**	**25.5**	**0.9911**

ME values in red are highlighted where they are < 0.6, indicating an acceptable but not good fit

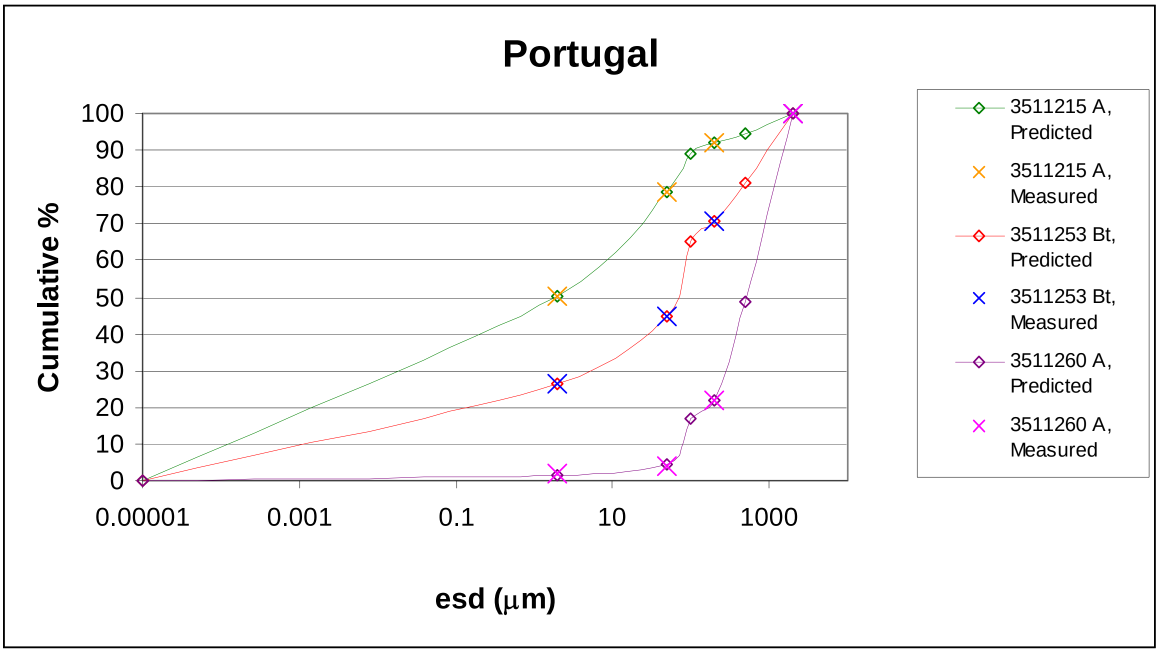


Figure 2. Interpolated and original particle-size data (esd – equivalent spherical diameter) for selected clayey, loamy and sandy particle-size data sets from Portugal.

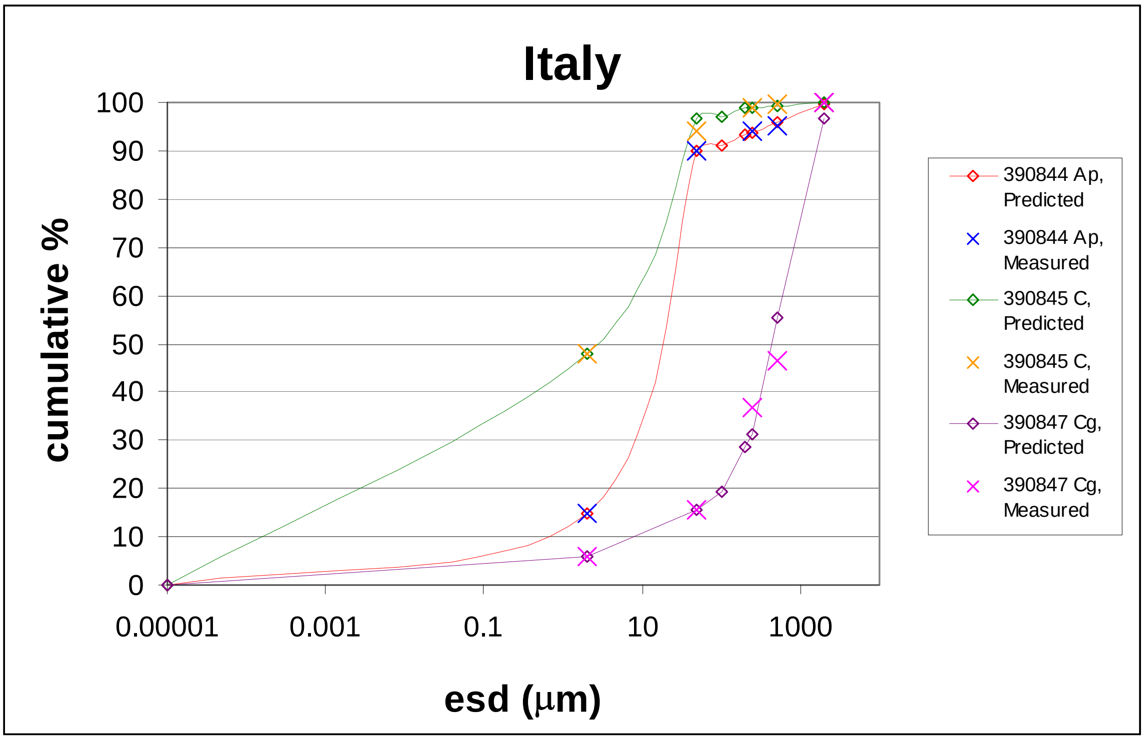


Figure 3. Interpolated and original particle-size data (esd – equivalent spherical diameter) for selected clayey, loamy and sandy particle-size data sets from Italy.

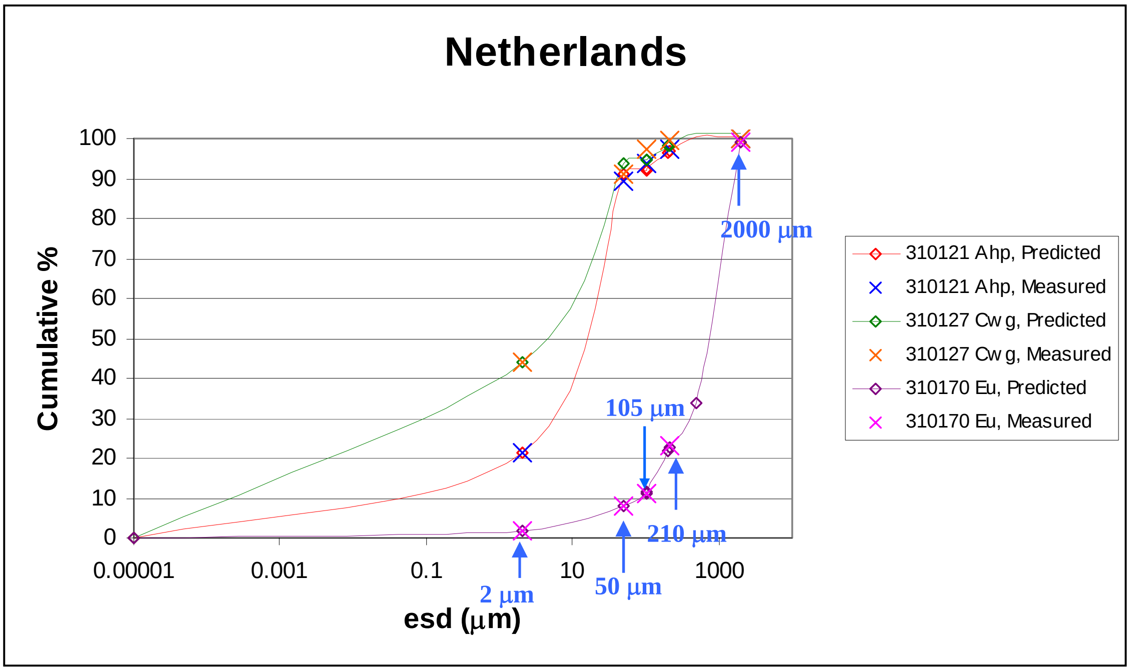


Figure 4. Interpolated and original particle-size data (esd – equivalent spherical diameter) for selected clayey, loamy and sandy particle-size data sets from Netherlands.

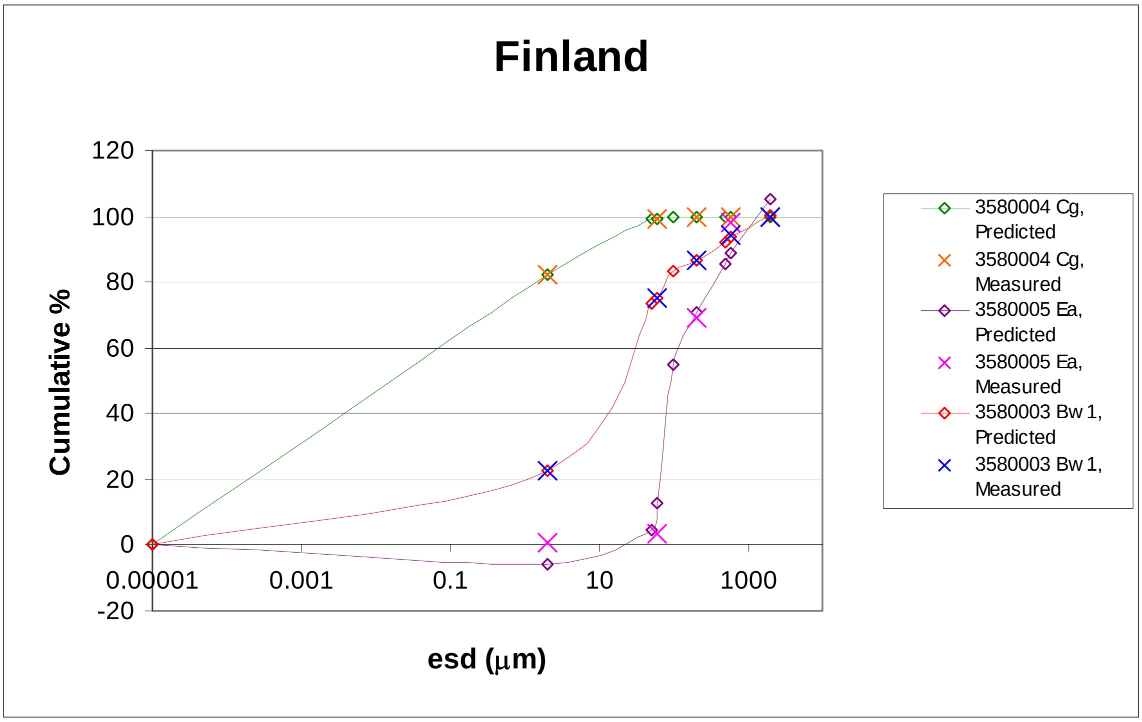


Figure 5. Interpolated and original particle-size data (esd – equivalent spherical diameter) for selected clayey, loamy and sandy particle-size data sets from Finland.

Organic carbon

The distribution of the organic carbon data supplied was examined to assess whether it conformed to the expected distributions for specific soil types and in comparison with other national data sets. Results are shown in Figures 6 to 10.

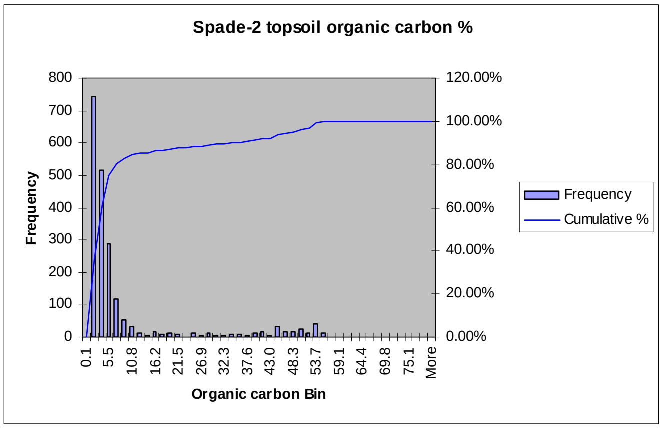
The distribution of all topsoil organic carbon contents (Figure 6) is clearly skewed with a bi-modal distribution reflecting the dominance of non-organic soils across Europe but also the presence of a significant number of organic soils. This distribution is to be expected.

Figures 7 to 9 show the topsoil organic carbon contents for three distinctive European soil types that would be expected to show different types of population distribution. Free draining, non-organic soils would be expected to have less topsoil organic carbon than would the wetter 'Gley' soils which are, or have been at some time in the past, seasonally waterlogged within 40 to 50 cm of the surface. They would also be expected to have less topsoil organic carbon than 'podzols' which originated as very acid soils where the turnover of organic matter was inhibited. These expected trends are confirmed by the descriptive statistics.

Figure 10 shows the population distribution of organic carbon content for all organic layers ('O' or 'H' horizons in the database). H horizons have developed because of prolonged wetness, whereas O horizons have developed under dry but very acid and/or cold conditions. The descriptive statistics show that the 'wet' organic H horizons have slightly greater organic carbon contents than the 'dry' O horizons and, again this trend is to be expected, although there is clearly considerable overlap in the populations because they are both organic in character.

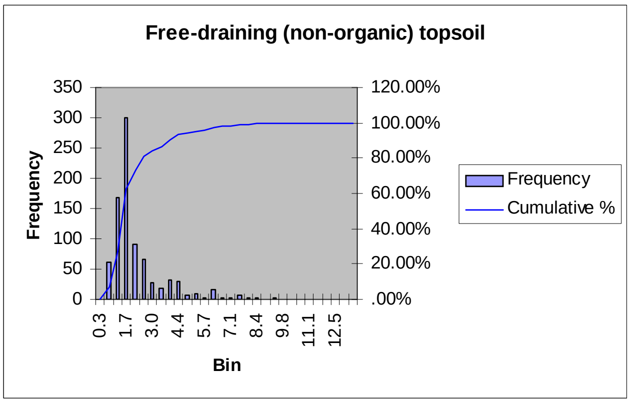
Finally, Figure 11 compares the relationship of topsoil organic carbon with clay content in the SPADE-2 database with that in the National Soil Inventory database for England & Wales (McGrath & Loveland, 1992). In both data sets, there is a lower limit for the relationship between organic carbon and clay, which probably reflects organic carbon that is strongly bound to clay complexes and cannot easily be decomposed. The slope of this relationship appears to be slightly lower for the SPADE-2 data than for the England and Wales data, which is likely to reflect the inclusion of data from more continental and Mediterranean countries where soils have undergone longer weathering under warmer conditions than in north-west Europe.

Overall the analysis carried out confirms that the trends and distribution of organic carbon contents in the SPADE-2 database are compatible with those expected for the range of soil types present.



Mean	8.249363
Standard Error	0.308866
Median	2.7
Mode	1.5
Standard Deviation	14.04915
Sample Variance	197.3785
Kurtosis	4.267769
Skewness	2.350113
Range	80.3
Minimum	0.2
Maximum	80.5
Sum	17067.93
Count	2069

Figure 6. Distribution and descriptive statistics of all topsoil organic carbon contents in SPADE-2



Mean	1.983665
Standard Error	0.051215
Median	1.5
Mode	1.5
Standard Deviation	1.494919
Sample Variance	2.234783
Kurtosis	9.998333
Skewness	2.648682
Range	13.1
Minimum	0.3
Maximum	13.4
Sum	1690.082
Count	852
Confidence Level(95.0%)	0.100523

Figure 7. Distribution and descriptive statistics of topsoil organic carbon contents in SPADE-2 for free-draining non-organic soils.

Mean	3.899782
Standard Error	0.293573
Median	3
Mode	1.5
Standard Deviation	3.079019
Sample Variance	9.480357
Kurtosis	2.229089
Skewness	1.484622
Range	14.5
Minimum	0.5
Maximum	15
Sum	428.976
Count	110
Confidence Level(95.0%)	0.581852

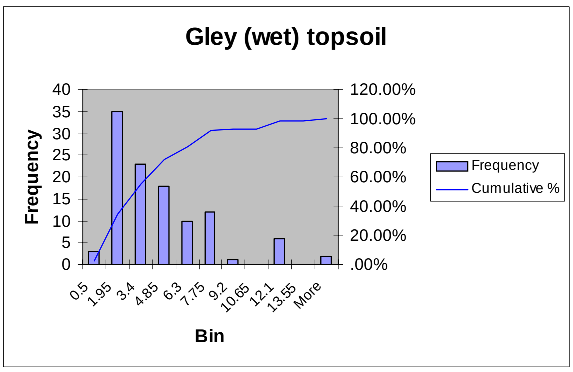
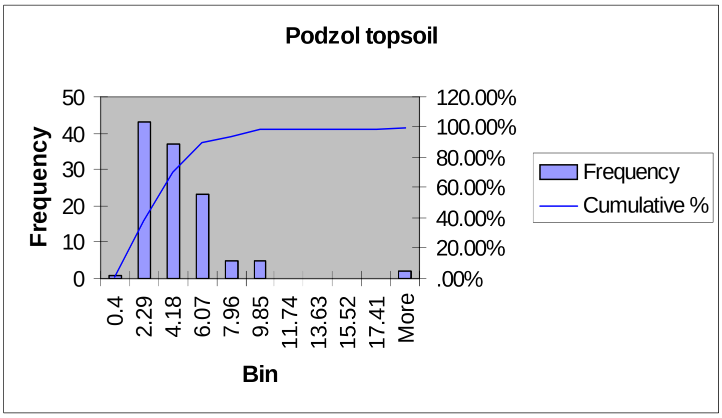
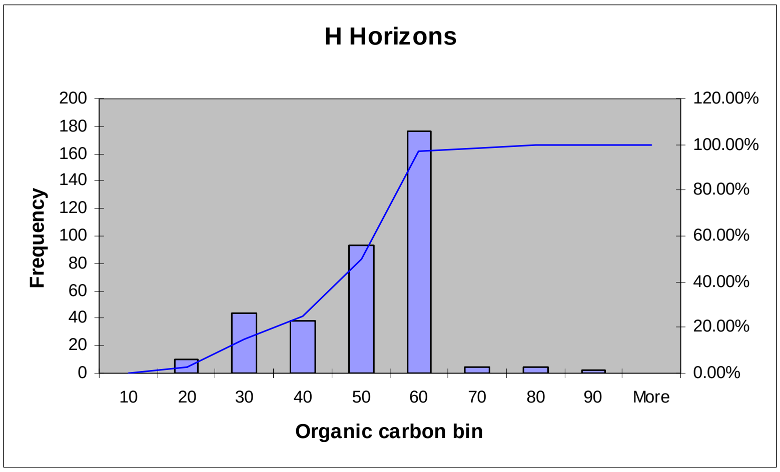


Figure 8. Distribution and descriptive statistics of topsoil organic carbon contents in SPADE-2 for all 'Gley' soils.

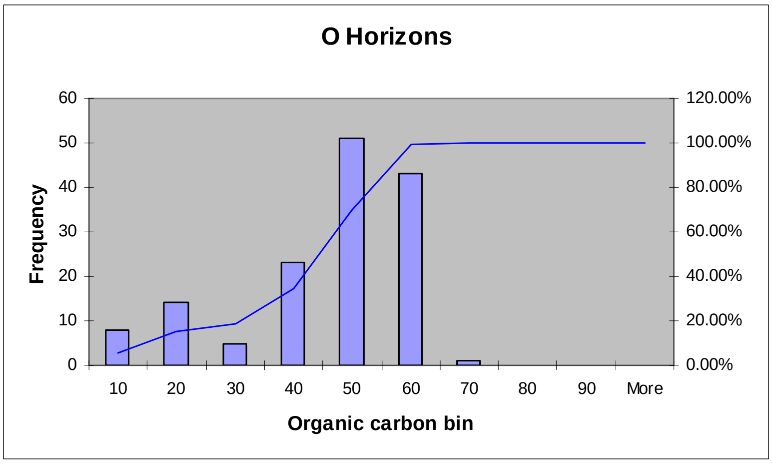


Mean	3.730182
Standard Error	0.262611
Median	3.953333
Mode	3.953333
Standard Deviation	2.828402
Sample Variance	7.999856
Kurtosis	14.40776
Skewness	3.050544
Range	18.9
Minimum	0.4
Maximum	19.3
Sum	432.7011
Count	116
Confidence Level(95.0%)	0.520181

Figure 9. Distribution and descriptive statistics of topsoil organic carbon contents in SPADE-2 for all 'Podzol' soils.



Mean	46.34364
Standard E	0.619074
Median	50.75942
Mode	49.2
Standard D	11.94026
Sample Va	142.5698
Kurtosis	0.37524
Skewness	-0.59889
Range	67.77
Minimum	12.73
Maximum	80.5
Sum	17239.83
Count	372



Mean	40.30709
Standard E	1.174065
Median	43
Mode	43
Standard D	14.18628
Sample Va	201.2505
Kurtosis	0.247982
Skewness	-1.084715
Range	60.6
Minimum	2
Maximum	62.6
Sum	5884.836
Count	146

Figure 10. Distribution and descriptive statistics of organic carbon contents in SPADE-2 for all 'wet' (H horizons) and 'dry' (O horizons) organic layers.

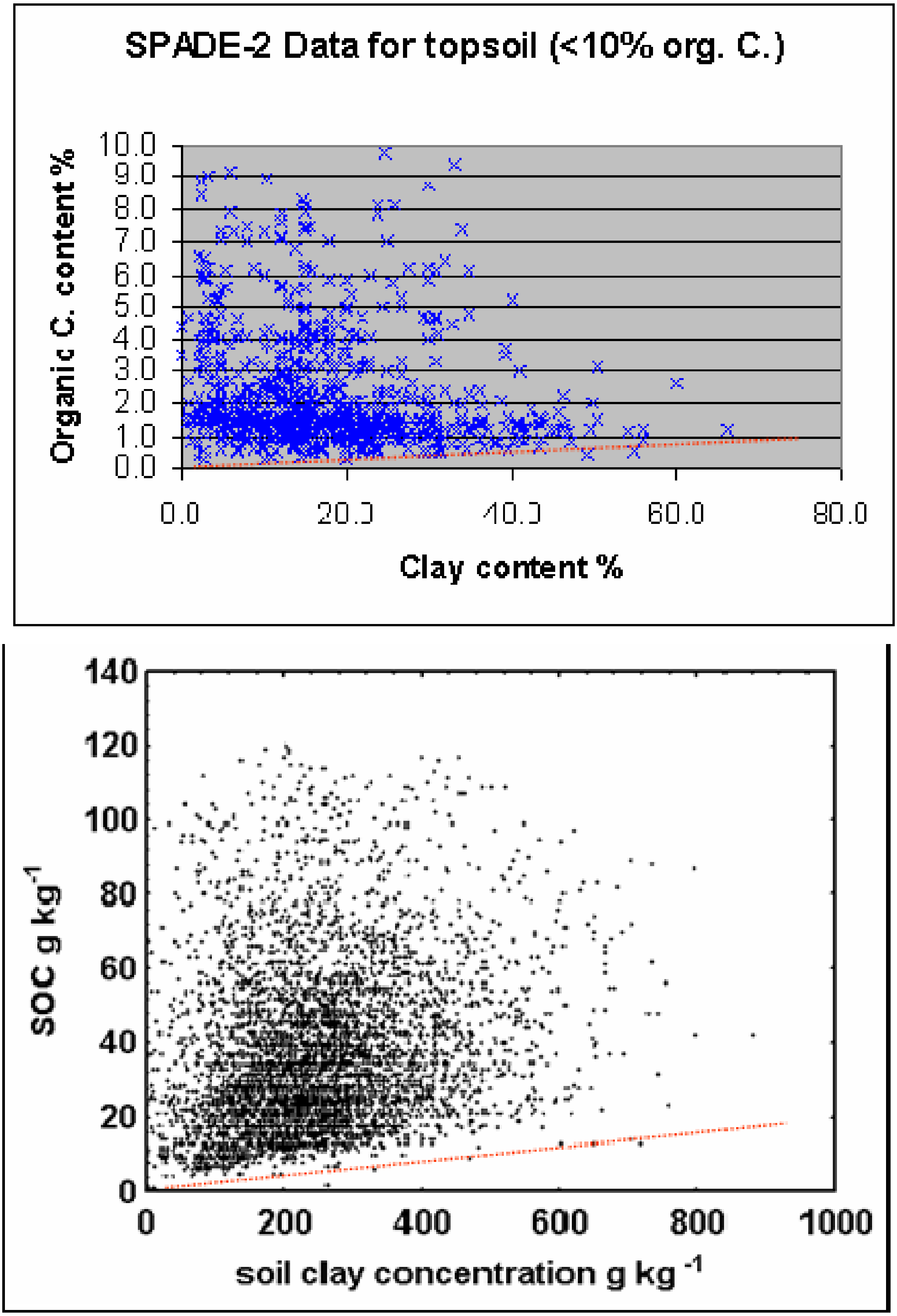


Figure 11. Relationship of (non-organic) topsoil organic carbon content with clay content for both the SPADE-2 database and the National Soil Inventory database for England and Wales.

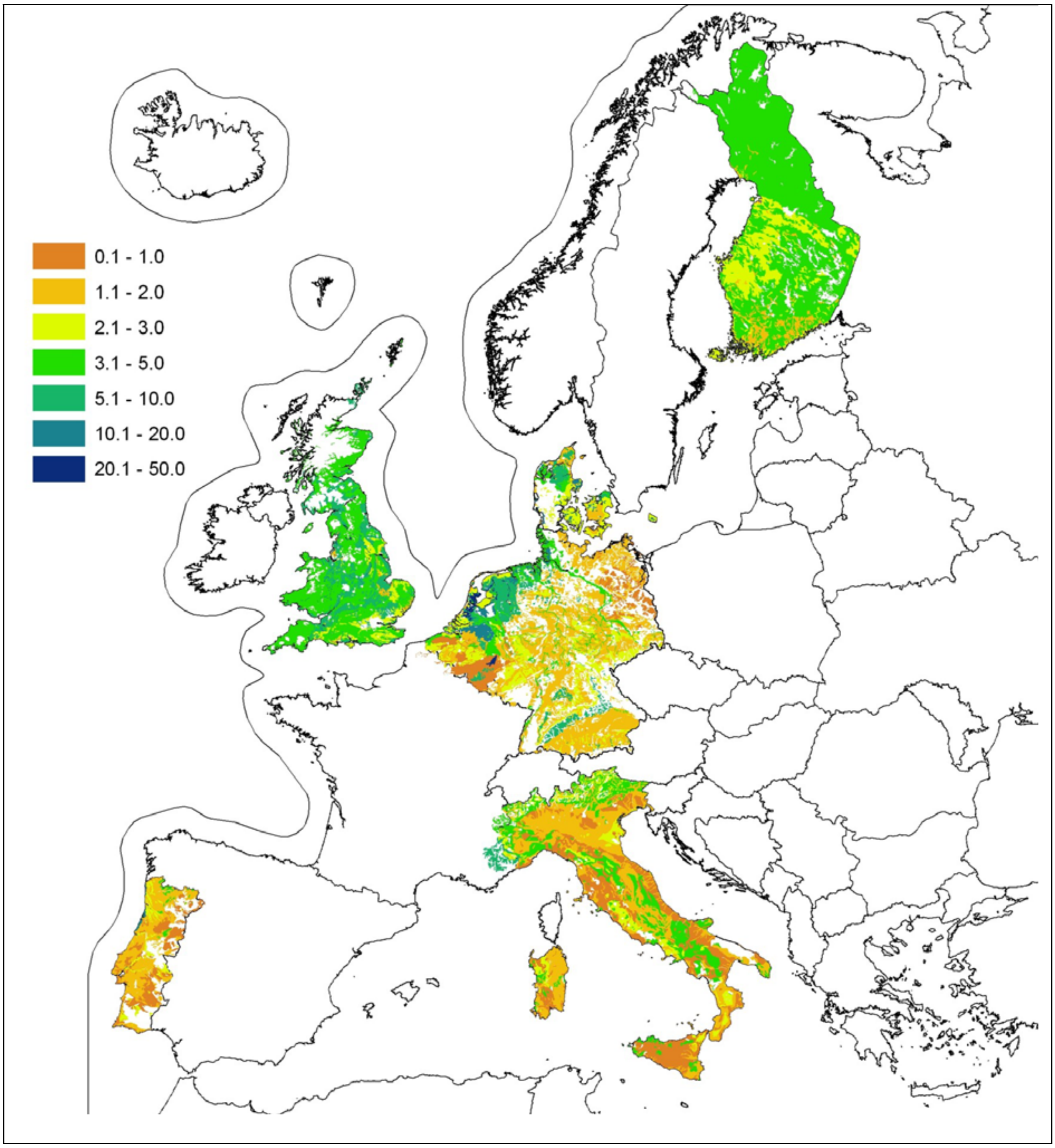


Figure 12. Weighted average agricultural topsoil organic carbon % for all SMUs containing any agricultural STU, based on SPADE-2 data.

Figure 12 shows the weighted average agricultural topsoil organic carbon content for all Soil Map Units that contain any 'agricultural' STU. 'Agricultural' STU were identified as those having a USE-1 or USE-2 designated as pasture/grassland, arable, horticulture, vineyards, arboriculture, industrial crops, rice, cotton, vegetables or olive trees.

pH

Descriptive statistics for pH for individual countries are shown in Tables 6 to 8. The climatic and parent material factors that influence soil pH, given the same kind of land use, mean that, in general, pH would be expected to be lower in northern and Western Europe and higher in southern and Eastern Europe. The data presented, therefore, group countries such as Belgium and Germany, and countries such as Italy and Portugal.

As expected, the data for Belgium and Germany show similar statistics (Table 6) with very similar mean and median values and range and mode values that are less than the median. However, the standard deviation of the data for Germany is slightly larger than that for Belgium, most likely because of its much greater area and diversity of soils.

The data for both countries contrast strongly with those for Italy (Table 7), which has much larger mean and median values a narrower range and a mode value that is higher than the median. Because of the strong Mediterranean influence, these contrasts in pH are to be expected.

Data for Portugal (Table 7) are intermediate between that for Belgium and Germany and that for Italy, with mean and median values closer to those of the former two countries than to those of Italy and the mode value lower than the median. The range of pH for Portugal is the largest of any of the countries shown. Again the overall trend of the data for Portugal is to be expected as it combines a strong maritime climatic influence, particularly in the north of the country with the higher temperatures and greater evapotranspiration of southern Europe.

As described in section 2.2, pH for the Netherlands was provided as measured in 0.1 M KCl and contrasts with all other pH data supplied, which are based on measurements in 1:2.5 soil:water solution. The pH data for the Netherlands is thus presented separately in Table 8. As would be expected from the different method used, pH data for the Netherlands has a lower mean and median value than that for Belgium and Germany and also has a smaller range.

The factor of 0.7 (FOCUS, 2000) to convert pH in water to pH in KCl was tested by comparing the median pH value for the Netherlands with that for Belgium and Germany. This gave a factor of 0.8 for conversion providing some confidence that, taking into account the difference in measurement method, the overall pH data for the Netherlands is comparable to that for the neighbouring countries of Belgium and Germany.

Overall, the pH data appear to be consistent with the patterns expected and do not show any unusual values outside an expected maximum range of about 2.5 to 9.0.

Figure 13 shows the distribution of topsoil pH values for the dominant agricultural STU within Soil Map Units, based on the SPADE-2 data. Agricultural STU were identified as those having a USE-1 or USE-2 designated as Pasture/grassland, arable, horticulture, vineyards, arboriculture, industrial crops, rice, cotton, vegetables or olive trees.

Table 6. Descriptive statistics for pH in soils of Belgium & Luxembourg and Germany from the SPADE-2 database.

Belgium pH		*Bin*	*Frequency*	*Cumulative %*
		3	2	.23%
Mean	5.689569	4	39	4.65%
Standard Error	0.033938	5	213	28.80%
Median	5.7	6	302	63.04%
Mode	5.4	7	240	90.25%
Standard Deviation	1.007894	8	81	99.43%
Sample Variance	1.01585	9	5	100.00%
Kurtosis	-0.433393	More	0	100.00%
Skewness	0.096931			
Range	5.5			
Minimum	2.7			
Maximum	8.2			
Sum	5018.2			
Count	882			
Confidence Level(95.0%)	0.066608			

Germany pH		*Bin*	*Frequency*	*Cumulative %*
		3	3	.63%
Mean	5.831513	4	32	7.35%
Standard Error	0.062563	5	130	34.66%
Median	5.7	6	105	56.72%
Mode	4.4	7	93	76.26%
Standard Deviation	1.364966	8	91	95.38%
Sample Variance	1.863131	9	22	100.00%
Kurtosis	-1.063897	More	0	100.00%
Skewness	0.080143			
Range	6			
Minimum	2.5			
Maximum	8.5			
Sum	2775.8			
Count	476			
Confidence Level(95.0%)	0.122935			

Table 7. Descriptive statistics for pH in soils of the Italy and Portugal from the SPADE-2 database.

Italy pH		*Bin*	*Frequency*	*Cumulative %*
		3	0	.00%
Mean	7.208051	4	0	.00%
Standard Error	0.034475	5	17	2.27%
Median	7.43	6	76	12.42%
Mode	8	7	207	40.05%
Standard Deviation	0.943503	8	298	79.84%
Sample Variance	0.890197	9	151	100.00%
Kurtosis	-0.508137	More	0	100.00%
Skewness	-0.587073			
Range	4.2			
Minimum	4.7			
Maximum	8.9			
Sum	5398.83			
Count	749			
Confidence Level(95.0%)	0.067679			

Portugal pH		*Bin*	*Frequency*	*Cumulative %*
		3	2	0.21%
Mean	6.288818	4	0	0.21%
Standard Error	0.033919	5	69	7.54%
Median	6	6	418	51.91%
Mode	5.8	7	242	77.60%
Standard Deviation	1.041035	8	129	91.30%
Sample Variance	1.083754	9	82	100.00%
Kurtosis	-0.155155	More	0	100.00%
Skewness	0.505485			
Range	6.5			
Minimum	2.4			
Maximum	8.9			
Sum	5924.067			
Count	942			

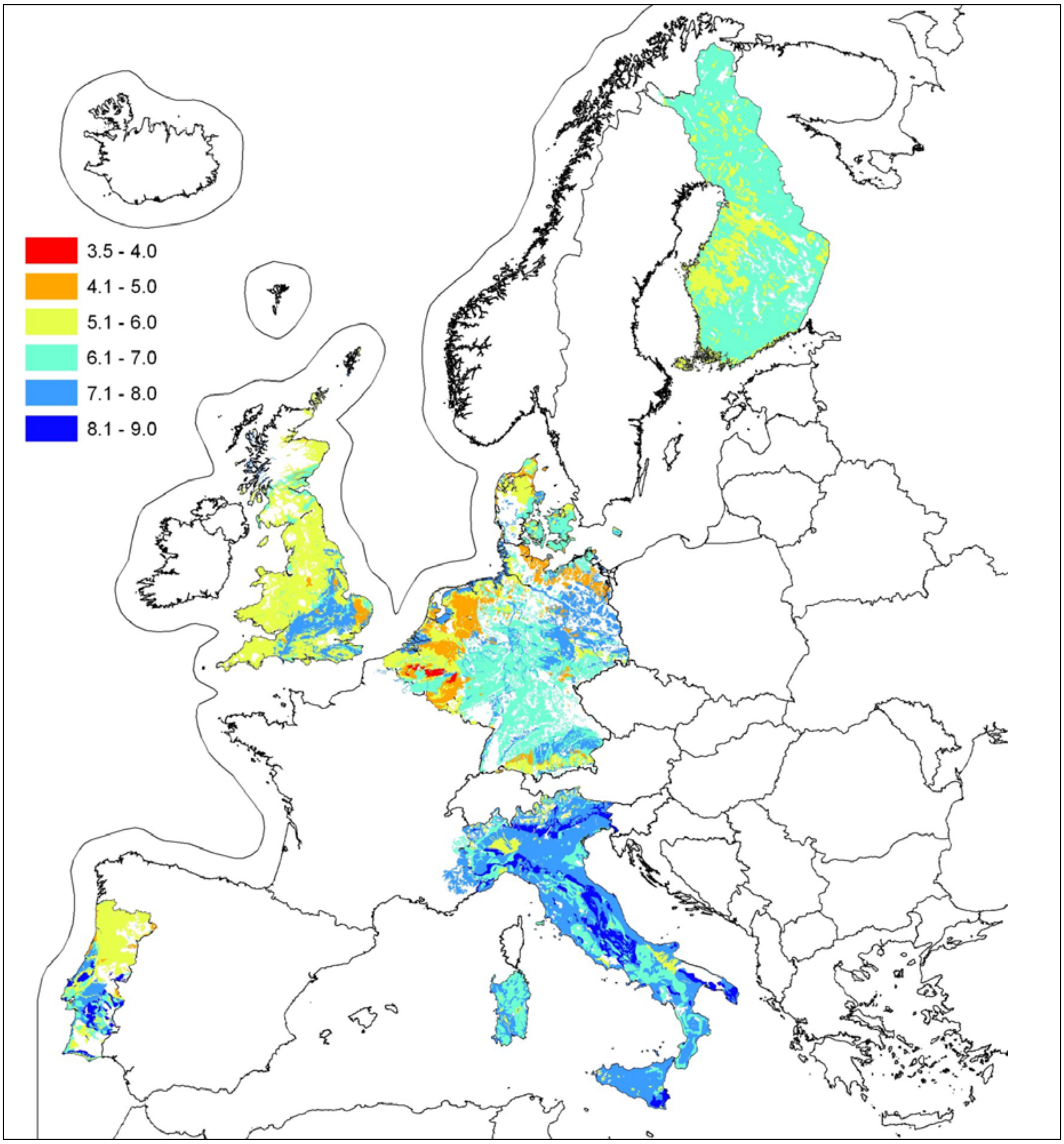


Figure 13. Topsoil pH of the dominant agricultural STU within an SMU based on SPADE-2 data.

Table 8. Descriptive statistics for pH in soils of the Netherlands from the SPADE-2 database.

Netherlands pH		*Bin*	*Frequency*	*Cumulative %*
		3	8	2.75%
Mean	4.900344	4	51	20.27%
Standard Error	0.064735	5	127	63.92%
Median	4.7	6	63	85.57%
Mode	4.2	7	18	91.75%
Standard Deviation	1.104302	8	24	100.00%
Sample Variance	1.219483	9	0	100.00%
Kurtosis	0.192669	More	0	100.00%
Skewness	0.721967			
Range	5			
Minimum	3			
Maximum	8			
Sum	1426			
Count	291			
Confidence Level(95.0%)	0.127411			

Bulk density

The data for bulk density provided for the SPADE-2 database were analysed according to the relationship with organic carbon content and total sand content, in order to identify any unusual outliers. Dry bulk density of soil is largely determined by the amount of consolidation present (normally larger in the lowest layers of the soil profile) the amount of organic matter present (organic matter is far less dense than mineral material) and the density of the mineral particles present. Sand particles represent the largest mineral size-fraction and, where other factors are the same, the greater the proportions present the greater the soil bulk density.

An initial analysis of the data identified some unusual outliers and their values were checked and corrected. Relationships for the resulting final data set are presented in Figures 14 and 15. Figure 14 shows the relationship of bulk density with organic carbon content for all soil layers in the database. Because of the low density of soil organic matter, as organic carbon content increases, it has an increasing effect on soil bulk density and, as would be expected from this, the data show a good exponential relationship (r^2 of 0.92).

However, the majority of data points are spread relatively widely where organic carbon contents are less than about 8%. In these soil layers, the influence of organic matter is much less significant and factors such as the density of mineral materials and level of consolidation become much more important.

Figure 15 therefore shows the relationship of bulk density with total sand content for all SPADE-2 soil layers that have an organic carbon content less than 8%. The relationship is a weak one but does show that, in general, bulk density increases as total sand content increases. The spread of data also appears to conform to what would be expected, with a greater spread of data points below the mean line than above it, reflecting the variable influence of organic matter and the impact of loosely consolidated materials such as alluvium, colluvium and wind blown deposits. Very few values are above a density of about 1.8, with the few that are related mainly to dense, soft rock layers.

Overall, the bulk density analyses show that the data in SPADE-2 appear to conform to the expected relationships with organic carbon and sand content, given the range of soil types and parent materials present across Europe.

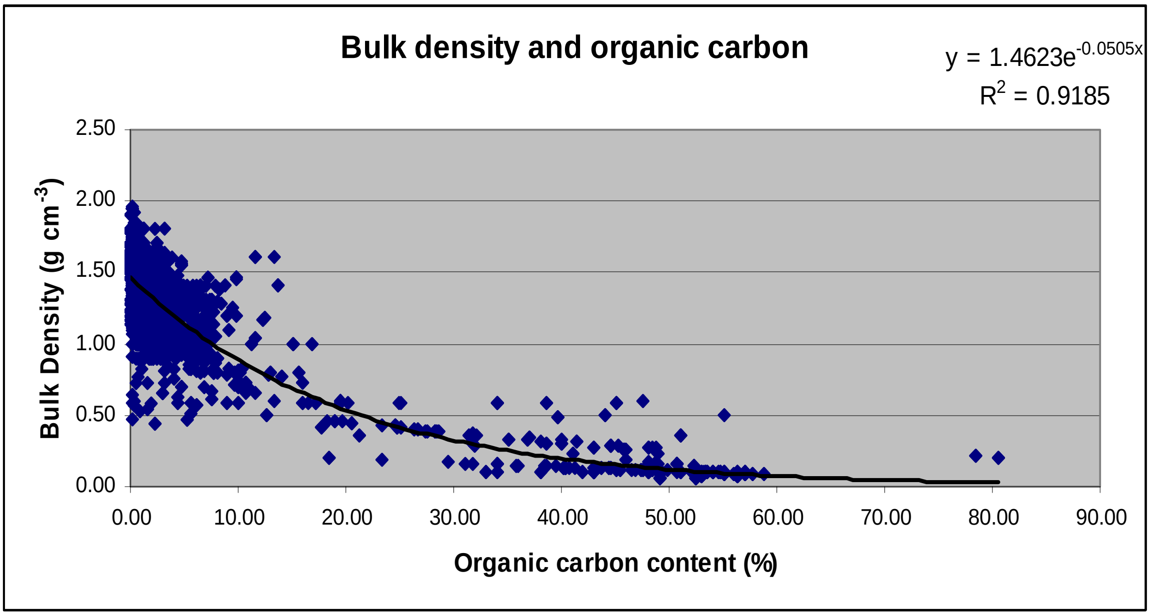


Figure 14. Relationship between bulk density and organic carbon, all data for all countries

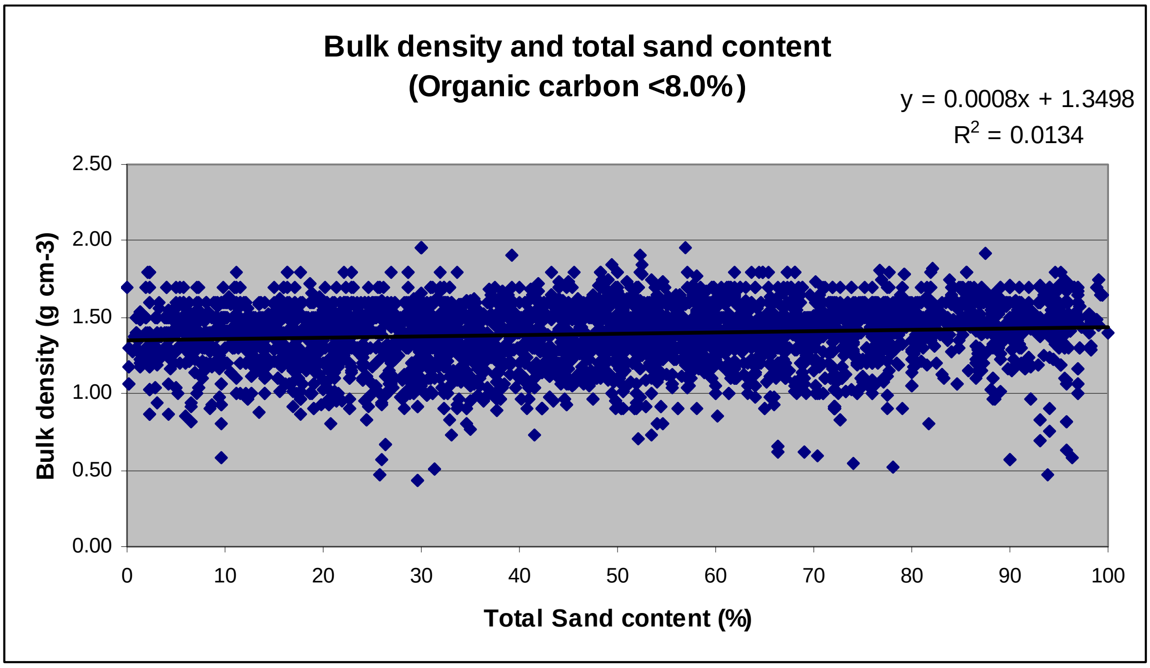


Figure 15. Relationship between bulk density and total sand content for all soils with <8.0% organic carbon

ACCESS TO AND USE OF THE SPADE-2 DATABASE

The SPADE-2 database, v. 1.0 comprises two separate sets of data files: SPADE_2_raw.xls; SPADE_2.dbf.

SPADE_2_raw.xls is a Microsoft EXCEL file comprising a set of worksheets each containing the raw data supplied by each national data provider. These data are included for completeness and future reference only. It is not intended that they be used to link with the spatial data held in the Soil Geographical Database of Europe (SGDBE).

Format of the SPADE_2.dbf file

The SPADE_2.dbf file comprises data in columns under the following category headings:

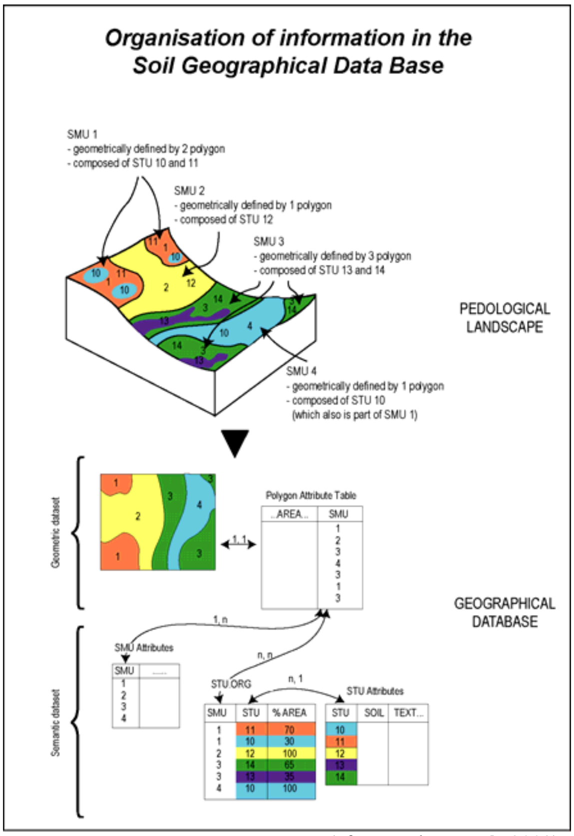
SMU; STU; USE; SOIL; PCAREA, HORIZON; DEPTH_UP; DEPTH_LO; CLAY; SILT; SAND-TOT; SAND_01; SAND_02; SAND_05; SAND_20; STONES; PH_KCL; PH_KCLSD; PH_H2O; PH_H2OSD; OC; OC_SD; DB; TEXT1; TEXT2; WR; WM1; WM2; WM3

The meaning of each of these categories is defined in Annex 3 along with the meaning of the numerical codes that are used to classify attributes in the USE; SOIL; TEXT1; TEXT2; WR; WM1; WM2 and WM3 columns.

All, missing data are coded as '-9999' to facilitate import into GIS and other software packages, e.g. statistical analysis software. Missing data most commonly occur in the columns relating to clay, silt and sand contents, for organic soil layers (coded 'H' or 'O' in the Layer column) and for all soil layer property data columns in rock layers (coded 'R' in the Layer column).

Missing data also commonly occur in the PH_KCLSD, PH_H2OSD and OC_SD columns, but here values of -1, -8 or -9 are used indicating that either the national data suppliers had insufficient data to derive a meaningful standard deviation value, or they used expert judgement to derive the property value, thus no standard deviation could be given.

It should be noted that the SPADE-2 database is made up of three separate types of data: Firstly, the soil property data for each soil HORIZON of each STU–land use combination. This is defined in columns headed HORIZON; DEPTH_UP; DEPTH_LO; CLAY; SILT; SAND-TOT; SAND_01; SAND_02; SAND_05; SAND_20; STONES; PH_KCL; PH_KCLSD; PH_H2O; PH_H2OSD; OC; OC_SD; DB. Only one line of data is included for each HORIZON.



(after Lambert *et al.*, 2003)

Figure 16. Data structure of the European Soil Database.

Secondly, there are data relating to each STU. This is defined in columns headed USE; SOIL; TEXT1; TEXT2; WR; WM1; WM2; WM3. These data are derived from the STU.dbf file of the SGDBE database and, for each STU-land use combination, is repeated for each soil HORIZON line. Finally, there are data relating to each SMU (soil map unit). This is defined in columns headed SMU, STU, PCAREA. These data are derived from the STUORG.dbf file of the SGDBE and, for each SMU-STU combination, is repeated for each soil HORIZON line.

Linking the soil property data to the soil geographical data

The SPADE-2 database can be most effectively used in conjunction with the Soil Geographical Database of Europe (SGDBE) – see Figure 16 providing the soil property data for the Soil Typological Units (STU). As mentioned above, a key database STUORG.dbf quantifies the relationship between the STU and Soil Mapping Units (SMU). Thus setting up a relational join in ArcView™ or ArcGIS™ or other GIS software allows the user to link the soil property data to the polygons displayed via the SGDBE. Spatial analysis is then possible. This must be undertaken with care because although STUORG.dbf identifies the proportion (%) of each STU in the SMU, the spatial occurrence of the STUs is not specified (Figure 17).

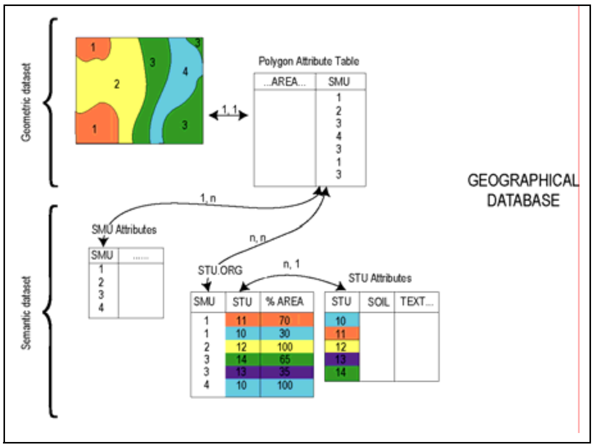


Figure 17. Data structure for STU.ORG.

Quantifying areas of selected soil types under specified land uses

In order to get an estimation of the area occupied by a mapped soil scenario, it is necessary to work with a joined Soil-SPADE_2.dbf file and to make some assumptions about the fraction of STU areas that are represented by their defined 'dominant' land use (USE1) and 'secondary' land use (USE2). The following procedure is suggested:

i. Open the SPADE_2.dbf file and make a selection using a soil scenario. Ensure that the scenario will only select a single STU line, for example where the Upper depth = 0 and the USE = 3. Export the selected lines as Soil***.dbf, to a scenario folder.

ii. Add Soil***.dbf to the work area and **link** it to 'soil.dbf'. The resulting map should highlight all the Soil Map Units (SMU) which contain the selected STU. Save the map as a record of where the selected soil scenario occurs. Export the selected soils as Soil***_selection.dbf to the scenario folder.

iii. Using Soil***.dbf, **join** the file to the STU.dbf file to create a Soil***_STU.dbf file. Export the file to the scenario folder.

iv. Outside of the GIS, open Soil***_selection.dbf and save as an MS Excel file. Use Excel to calculate the total area of each **SMU** in the file.

v. Outside of the GIS, open Soil***_STU.dbf and save as an MS Excel file. Add the calculated total area of each SMU to the Soil***_STU.xls file.

vi. Add a column to the Soil***_STU.xls file headed *USE_fraction*. Using MS Excel, create a formula in the first cell in the column, to calculate the USE_fraction as follows: =**IF(AND(USE1 cell = scenario use code, USE2 cell = 0), 0.8, IF(USE1 cell = scenario use code, 0.6, IF(USE2 cell = scenario use code, 0.3,0)))**. Copy this formula to all cells in the column.

vii. Using MS Excel, add a column to the Soil***_STU.xls file headed *STU_areas*. Create a formula in the first cell of the column, to calculate the scenario-specific use area of each STU as follows: = (SMU_area cell) * (PC_AREA cell/100) * (Use_fraction cell).

viii. Using MS Excel, SUM all the values in the *STU_areas* column. This value is the estimated area of the selected soil scenario. The calculation is based on the following broad assumptions:

1. Where an STU has values for USE1 only (i.e. USE2 is 0), that use covers 0.8 of the total area of the STU;
2. Where an STU has values for both USE1 and USE2, USE1 occupies 0.6 of the total STU area, and USE2 occupies 0.3 of the total STU area (this means that 0.1 of the area cannot be assigned a specific land use).
3. Where the scenario USE does not match either the USE1 or USE2 values, the scenario use does not occupy any of the STU area.

CONCLUSIONS

The new SPADE-2 database contains profile data characterising virtually all the Soil Typological Units within the 1:1,000,000 scale Soil Map Units covering Belgium, Denmark, England, Finland, Germany, Italy, Luxembourg, Netherlands Portugal, Scotland and Wales.

The raw data supplied by national data providers has been harmonised and validated to provide a single data file (SPADE_2.dbf) that can be easily used in conjunction with the SGDBE. The data file comprises 1897 soil profiles directly linked to 1077 STU (35% of all STU for the 15 countries) and fully characterising 313 SMUs of the SGDBE. Of the 1897 SPADE-2 profiles included, 1288 have an agricultural land use and the remainder represent a variety of non-agricultural land uses. The number of profiles within the SPADE_2.dbf file is summarised in Table 9.

Although the SPADE_2 database represents a comprehensive expansion and increase in utility of the soil property data in SPADE-1 (v.2.1.0.0), when working at a European level there remain some significant gaps. It is therefore recommended that continuing efforts are made to obtain and harmonise data from countries that did not supply data for this version of SPADE-2.

It is further recommended that the database and methods used to derive it be extended to include soil property data from the New Member States of the Enlarged EU, the former EFTA nations (Norway & Switzerland), Candidate Countries (Bulgaria, Croatia & Romania), and the Neighbouring Countries of the Western Balkans.

Table 9. SPADE-2 Profiles and links to STU on a land use basis.

Land Use	Total STU (dominant land use)	Total SPADE-2 profiles (dominant & secondary land use)	With an explicit link to an STU
No specified land use	23	8	8
“Agriculture”	0	0	0
Arable	1206	632	632
Grassland	547	483	483
Extensive pasture	114	94	94
Horticulture	15	62	62
Vineyards	15	33	33
Orchards	5	17	17
Industrial Crops	5	5	5
Rice	4	6	6
Cotton	3	0	0
Olives	17	38	38
Vegetables	0	0	0
Poplars		12	12
Non agricultural	1206	601	601
Totals	**3164**	**1897**	**1897**

CD ROM

The SPADE-2 will be distributed in future as part of the European Soil Database v 3.0. The SPADE-2.DBF file and SPADE_2_raw.xls, containing the original national data, are included for restricted circulation on a CD that is available with this report.

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REFERENCES

Breuning-Madsen, H. & Jones, R.J.A. (1995). Soil profile analytical database for the European Union. Danish Journal of Geography (95):49-57.

Breuning-Madsen, H. & Jones, R.J.A. (1998): Towards a European Soil Profile Analytical Database. Pp. 43-50. in: Heineke, H.J., W. Eckelmann, A.J. Thomasson, R.J.A. Jones, L. Montanarella and B. Buckley (eds.): Land Information Systems: Developments for planning the sustainable use of land resources. European Soil Bureau Research Report No.4. EUR 17729 EN. Office for Official Publications of the European Communities, Luxembourg.

CEC (1985). Soil Map of the European Communities, 1:1,000,000. 124pp. and 7 maps. Office for Official Publications of the European Communities, Luxembourg.

FAO (1990). Guidelines for Soil Description. 3rd edition (Revised). FAO, Rome, 70pp.

FAO (1998). World Reference Base for Soil Resources. World Soil Resources Report No. 84, Rome 88pp.

FOCUS (2000). FOCUS groundwater scenarios in the EU review of active substances. Report of the FOCUS groundwater scenario working group. EC document ref. SANCO/321/2000 rev2.

Lambert, J.J., Daroussin, J., Eimberck,, M., Le Bas, C., Jamagne, M., King, D. & Montanarella, L. (2003). Soil Geographical Database for Eurasia & The Mediterranean: Instructions Guide for Elaboration at scale 1:1,000,000. Version 4.0. EUR 20422 EN, 64pp. Office for Official Publications of the European Communities, Luxembourg.

Madsen, H. B. (1991): The principles for construction of an EC-soil database system. Pp. 173-180. In: Hodgson, J.M. (ed.): Soil survey – a basis for soil protection. Soil and Groundwater Research Report I. EUR 13340 EN. Office for Official Publications of the European Communities, Luxembourg.

Madsen H. B. & Jones, R.J.A. (1995a): The establishment of a soil profile analytical database for the European Union. Pp. 55-63. In: King, D., R.J.A. Jones & A.J. Thomasson (eds.): European Land Information Systems for Agro-environmental Monitoring. EUR 16232 EN. Office for Official Publications of the European Communities, Luxembourg.

Madsen, H.B. & Jones, R.J.A. (1995b): Guidelines for completing profile proformas. Pp. 277-284. in: King, D., R.J.A. Jones & A.J. Thomasson (eds.): European Land Information Systems for Agro-environmental Monitoring. EUR 16232 EN. Office for Official Publications of the European Communities, Luxembourg.

McGrath, S.P. & Loveland, P.J. (1992). The Soil Geochemical Atlas of England and Wales. Blackie Academic and Professional, Glasgow.

Melacini, A, Walker, A & Gunther, P. (1995). Statistical Approaches. In Walker, A., Calvet, R., Del Re, A.A.M., Pestemer, W. & Hollis, J.M. (Eds.). Evaluation and improvement of mathematical models of pesticide mobility in soils and assessment of their potential to predict contamination of water systems. Hrsg. Von der Biologischen für Land- und Forstwirtschaft Berlin-Dahlem. Blackwell Wissenschafts - Verlag GmbH Berlin/Wien. pp. 23-31.

Montanarella, L., Jones, R.J.A. & Dusart, J. (2005). The European Soil Bureau Network. In: R.J.A. Jones, B. Houskova, Bullock, P. and L. Montanarella (eds). Soil Resources of Europe: second edition. European Soil Bureau Research Report No.9, EUR 20559 EN, (2005), p.3-14.

Platou, S.W., Nørr, A.H. & Madsen, H.B. (1989): Digitisation of the EC Soil Map. In: Jones, R.J.A. and B. Biagi (eds.): Agriculture: computerization of land use data. EUR 11151 EN, p.12-24. Office for Official Publications of the European Communities, Luxembourg.

Tinsley, J. (1950). The determination of organic carbon in soils by dichromate mixtures. Transactions of the 4th International Congress of Soil Science 1, 161-4.

Van Genuchten, M.Th. & Leij, F.J. (1992). On estimating the hydraulic properties of unsaturated soils. In: M.Th. van Genuchten, F.J. Leij and L.J. Lund (eds), Indirect mehtods for estimating the hydraulic properties of unsaturated soils. Proc. International Workshop on Indirect methods for Estimating the Hydraulic Properties of Unsaturated Soils. Riverside California, 11-13 October 1989, p. 1-14.

Walkley, A. & Black, I.A. (1934). An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. Soil Science, 34, 29-38.

Wösten, J.H.M., Lilly. A., Nemes, A. & Le Bas, C. (1998). Using existing soil data to derive hydraulic parameters for simulation models in envrionmental studies and in land use planning. Final report on the European Union funded project 1998. DLO Winand Staring Centre Report No.156, 106pp. ISBN 0927-4537, Wageningen, The Netherlands.

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ANNEX 3: Data Dictionary

Field names for SPADE-2 Database

Field Name	Width	Type	Description
SMU	6	Integer	Soil Mapping Unit code [1]
STU	6	Integer	Soil Typological Unit code [1]
USE	2	Integer	Land use class [1]
SOIL	4	Character	Soil name FAO Legend 1974 modified CEC 1985 [1]
PCAREA	3	Integer	(STUarea/SMUarea)100
HORIZON	4	Character	FAO Nomenclature [1]
DEPTH_UP	3	Integer	Upper depth (cm)
DEPTH_LO	3	Integer	Lower depth (cm)
CLAY	3	Integer	Clay <0.002mm esd, % oven dry weight (at 105°C)
SILT	3	Integer	Silt 0.002-0.05mm esd, % oven dry weight (at 105°C)
SAND_TOT	3	Integer	Sand 0.05-2mm esd, % oven dry weight (at 105°C)
SAND_01	3	Integer	Sand 0.05-0.01mm esd, % oven dry weight (at 105°C)
SAND_02	3	Integer	Sand 0.01-0.02mm esd, % oven dry weight (at 105°C)
SAND_05	3	Integer	Sand 0.02-0.05mm esd, % oven dry weight (at 105°C)
SAND_20	3	Integer	Sand 0.05-2mm esd, % oven dry weight (at 105°C)
STONES	3	Integer	Stone content as volume %
PH_KCL	4	Real	pH in 0.1 M KCL soln.
PH_KCLSD	4	Real	Standard Deviation of pH in KCL
PH_H2O	4	Real	pH in H2O soln. (soil: water ratio 1:2.5)
PH_H2OSD	4	Real	Standard Deviation of pH in H2O
OC	4	Real	Organic Carbon content %
OC_SD	4	Real	Organic Carbon standard deviation
DB	4	Real	Bulk Density %
TEXT1	1	Integer	Dominant surface textural class [1, 2]
REXT2	1	Integer	Secondary surface textural class[1, 2]
WR	1	Integer	Dominant annual average water regime class[1, 2]
WM1	1	Integer	Water management in agricultural land[1, 2]
WM2	1	Integer	Purpose of water management system[1, 2]
WM3	1	Integer	Type of water management system[1, 2]

[1] See below for code and attribute descriptions [2] STU attributes

SOIL	Full 1974 (modified CEC 1985) FAO-Unesco legend soil name.
(Present in:	*STU)*
	No information
A	Acrisol
Af	Ferric Acrisol
Ag	Gleyic Acrisol
Ah	Humic Acrisol
Ao	Orthic Acrisol
Ap	Plinthic Acrisol
B	Cambisol
Ba	Calcaric Cambisol
Bc	Chromic Cambisol
Bcc	Calcaro-Chromic Cambisol
Bch	Humo-Chromic Cambisol
Bck	Calci-Chromic Cambisol
Bd	Dystric Cambisol
Bda	Ando-Dystric Cambisol
Bdg	Gleyo-Dystric Cambisol
Bds	Spodo-Dystric Cambisol
Be	Eutric Cambisol
Bea	Ando-Eutric Cambisol
Bec	Calcaro-Eutric Cambisol
Bef	Fluvi-Eutric Cambisol
Beg	Gleyo-Eutric Cambisol
Bev	Verti-Eutric Cambisol
Bg	Gleyic Cambisol
Bgc	Calcaro-Gleyic Cambisol

Bge	Eutri-Gleyic Cambisol
Bgg	Stagno-Gleyic Cambisol
Bgs	Spodo-Gleyic Cambisol
Bh	Humic Cambisol
Bhc	Calcaro-Humic Cambisol
Bk	Calcic Cambisol
Bkf	Fluvi-Calcic Cambisol
Bkh	Humo-Calcic Cambisol
Bkv	Verti-Calcic Cambisol
Bv	Vertic Cambisol
Bvc	Calcaro-Vertic Cambisol
Bvg	Gleyo-Vertic Cambisol
Bvk	Calci-Vertic Cambisol
Bx	Gelic Cambisol
Bxs	Spodo-Gelic Cambisol
C	Chernozem
Ch	Haplic Chernozem
Chp	Pachi-Haplic Chernozem
Chv	Verti-Haplic Chernozem
Ck	Calcic Chernozem
Ckb	Vermi-Calcic Chernozem
Ckc	Calcaro-Calcic Chernozem
Ckcb	Vermi-Calcaro-Calcic Chernozem
Ckp	Pachi-Calcic Chernozem
Cl	Luvic Chernozem
D	Podzoluvisol
Dd	Dystric Podzoluvisol
De	Eutric Podzoluvisol
Dg	Gleyic Podzoluvisol
Dgd	Dystric Gleyic Podzoluvisol
Dge	Eutric Gleyic Podzoluvisol
Dgs	Stagno-Gleyic Podzoluvisol
E	Rendzina
Ec	Cambic Rendzina
Eh	Histic Rendzina
Eo	Orthic Rendzina
F	Ferralsol
Fo	Orthic Ferralsol
G	Gleysol
Gc	Calcaric Gleysol
Gcf	Fluvi-Calcaric Gleysol
Gcs	Stagno-Calcaric Gleysol
Gd	Dystric Gleysol
Gdf	Fluvi-Dystric Gleysol
Gds	Stagno-Dystric Gleysol
Ge	Eutric Gleysol
Gef	Fluvi-Eutric Gleysol
Ges	Stagno-Eutric Gleysol
Gev	Verti-Eutric Gleysol
Gf	Fluvic Gleysol
Gfm	Molli-Fluvic Gleysol
Gh	Humic Gleysol
Ghf	Fluvi-Humic Gleysol
Ghh	Histo-Humic Gleysol
Ght	Thioni-Humic Gleysol
Gi	Histic Gleysol
Gih	Humo-Histic Gleysol
Gl	Luvic Gleysol
Gls	Stagno-Luvic Gleysol
Gm	Mollic Gleysol
Gmc	Calcaro-Mollic Gleysol
Gmf	Fluvi-Mollic Gleysol
Gmv	Verti-Mollic Gleysol
Gs	Stagnic Gleysol
Gt	Thionic Gleysol
H	Phaeozem
Hc	Calcaric Phaeozem
Hcf	Fluvi-Calcaric Phaeozem
Hcn	Alkalino-Calcaric Phaeozem
Hcs	Saline-Calcaric Phaeozem
Hg	Gleyic Phaeozem
Hgc	Calcaro-Gleyic Phaeozem
Hgf	Fluvi-Gleyic Phaeozem
Hgs	Stagno-Gleyic Phaeozem
Hgv	Verti-Gleyic Phaeozem
Hh	Haplic Phaeozem
Hhv	Verti-Haplic Phaeozem
Hl	Luvic Phaeozem
Hlv	Verti-Luvic Phaeozem
Ho	Orthic Phaeozem
I	Lithosol
Ic	Calcaric Lithosol
Ich	Humo-Calcaric Lithosol
Id	Dystric Lithosol
Ie	Eutric Lithosol
J	Fluvisol
Jc	Calcaric Fluvisol
Jcf	Fluvi-Calcaric Fluvisol
Jcg	Gleyo-Calcaric Fluvisol
Jd	Dystric Fluvisol
Jdf	Fluvi-Dystric Fluvisol
Jdg	Gleyo-Dystric Fluvisol
Je	Eutric Fluvisol
Jef	Fluvi-Eutric Fluvisol
Jeg	Gleyo-Eutric Fluvisol
Jm	Mollic Fluvisol
Jmg	Gleyo-Mollic Fluvisol
Jmv	Verti-Mollic Fluvisol
Jt	Thionic Fluvisol
K	Kastanozem
Kh	Haplic Kastanozem
Khb	Vermi-Haplic Kastanozem
Kk	Calcic Kastanozem
Kkb	Vermi-Calcic Kastanozem
Kkv	Verti-Calcic Kastanozem
Kl	Luvic Kastanozem
Ko	Orthic Kastanozem
L	Luvisol
La	Albic Luvisol

Lap	Plano-Albic Luvisol
Lc	Chromic Luvisol
Lcp	Plano-Chromic Luvisol
Lcr	Rhodo-Chromic Luvisol
Lcv	Verti-Chromic Luvisol
Ld	Dystric Luvisol
Ldg	Gleyo-Dystric Luvisol
Lf	Ferric Luvisol
Lg	Gleyic Luvisol
Lga	Albo-Gleyic Luvisol
Lgp	Plano-Gleyic Luvisol
Lgs	Stagno-Gleyic Luvisol
Lh	Humic Luvisol
Lk	Calcic Luvisol
Lkc	Chromo-Calcic Luvisol
Lkcr	Rhodo-Chromo-Calcic Luvisol
Lkv	Verti-Calcic Luvisol
Lo	Orthic Luvisol
Lop	Plano-Orthic Luvisol
Lp	Plinthic Luvisol
Ls	Spodic Luvisol
Lv	Vertic Luvisol
Lvc	Chromo-Vertic Luvisol
Lvcr	Rhodo-Chromo-Vertic Luvisol
Lvk	Calci-Vertic Luvisol
M	Greyzem
Mo	Orthic Greyzem
O	Histosol
Od	Dystric Histosol
Odp	Placi-Dystric Histosol
Oe	Eutric Histosol
Ox	Gelic Histosol
P	Podzol
Pf	Ferric Podzol
Pg	Gleyic Podzol
Pgh	Histo-Gleyic Podzol
Pgs	Stagno-Gleyic Podzol
Ph	Humic Podzol
Phf	Ferro-Humic Podzol
Pl	Leptic Podzol
Plh	Humo-Leptic Podzol
Po	Orthic Podzol
Pof	Ferro-Orthic Podzol
Poh	Humo-Orthic Podzol
Pol	Lepto-Orthic Podzol
Pp	Placic Podzol
Pph	Humo-Placic Podzol
Q	Arenosol
Qa	Albic Arenosol
Qc	Cambic Arenosol
Qcc	Calcaro-Cambic Arenosol
Qcd	Dystri-Cambic Arenosol
Qcg	Gleyo-Cambic Arenosol
Qcs	Spodo-Cambic Arenosol
Ql	Luvic Arenosol
Qld	Dystri-Luvic Arenosol
Qlg	Gleyo-Luvic Arenosol
R	Regosol
Rc	Calcaric Regosol
Rd	Dystric Regosol
Re	Eutric Regosol
S	Solonetz
Sg	Gleyic Solonetz
Sm	Mollic Solonetz
So	Orthic Solonetz
Sof	Fluvi-Orthic Solonetz
T	Andosol
Th	Humic Andosol
Tm	Mollic Andosol
To	Ochric Andosol
Tv	Vitric Andosol
U	Ranker
Ud	Dystric Ranker
Ul	Luvic Ranker
V	Vertisol
Vc	Chromic Vertisol
Vcc	Calcaro-Chromic Vertisol
Vg	Gleyic Vertisol
Vp	Pellic Vertisol
Vpc	Calcaro-Pellic Vertisol
Vpg	Gleyo-Pellic Vertisol
Vpn	Sodi-Pellic Vertisol
W	Planosol
Wd	Dystric Planosol
Wdv	Verti-Dystric Planosol
We	Eutric Planosol
Wev	Verti-Eutric Planosol
Wm	Mollic Planosol
X	Xerosol
Xk	Calcic Xerosol
Xl	Luvic Xerosol
Xy	Gypsic Xerosol
Z	Solonchak
Zg	Gleyic Solonchak
Zgf	Fluvi-Gleyic Solonchak
Zo	Orthic Solonchak
Zt	Takyric Solonchak
g	Glacier
p	Plaggensol
r	Rock Outcrop
Gtz	Undefined code
Rds	Undefined code
Vgs	Undefined code

Horizon Nomenclature

Horizon nomenclature follows that defined by FAO (1990).

Master horizons

The upper case (Capital) letters H, O, A, B, C and represent master horizons (soil layers). These capital letters are the base symbols to which other characters are added to complete the designation. Most horizons and layers are given a single capital letter but some require two.

Horizon designation	**Description**
H	Layers dominated by organic material, formed from accumulations of undecomposed or partially decomposed organic material at the surface.
O	Layers dominated by organic material, consisting of undecomposed or partially decomposed litter, such as leaves, needles, twigs, moss and lichens, which has accumulated on the surface.
A	Mineral horizons which formed at the surface or below an O horizon in which all or much of the original rock structure has been obliterated.
E	Mineral horixzons in which the main feature is loss of silicate clay, iron, aluminium, or some combination of these, leaving a concentration of sand and silt particles, and in which all or much of the rock structure has been obliterated.
B	Horizons that formed under an A, E, O or H horizon and in which the dominant features are the obliteration of all or much of the original rock structure.
C	Horizons or layers, excluding hard bedrock, that are little or affected by pedological processes and lack properties of H, O, A, E or B horizons
R	Hard bedrock underlying the soil.
AB, EB etc	Transitional horizons with properties of two horizons superimposed or the two properties separate.

Subordinate characteristics within master horizons

Symbol	Description	Properties
b	Buried genetic horizon	Identifiable material formed before burial
c	Concretions or nodules	Significant accumulations
f	Frozen soil	Contain permanent ice or permanently colder than 0 degC
g	Strong gleying	Distinct pattern of mottling occurs; (g) weak gleying
h	Accumulation of organic matter	
j	Jarosite mottles	
k	Accumulation of carbonates	Commonly calcium carbonate
m	Cementation or induration	Continuous (or nearly so) cementation
n	Accumulation of sodium	Exchangeable Na
o	Residual accumulation of sesquioxides	
p	Ploughing or other disturbance	e.g tillage practices
q	Accumulation of silica (secondary)	
r	Strong reduction	Indicating reduction of iron
s	Illuvial accumulation of sesquioxides	Including dispersible organic matter – sesquioxide complexes
t	Accumulation of silicate clay	Formed in situ or moved to it by illuviation
v	Occurrence of Plinthite	Iron-rich humus-poor material
w	Development of colour or structure	
x	Fragipan characteristics	Genetically developed firmness, brittleness or high bulk density
y	Accumulation of gypsum	
z	Accumulation of salts more soluble than gypsum	

The following changes were made to horizon nomenclature supplied by National experts:
Bsh → Bhs, Ah/Cw → A/C, CwBw → BCw, BW → Bw, Bpodz → Bs, Thin Ironpan → Bfe.

Land Use

USE1	Dominant land use.
USE2	Secondary land use.
(Present in:	*STU)*
0	No information
1	Pasture, grassland, grazing land
2	Poplars
3	Arable land, cereals
4	Wasteland, shrub
5	Forest, coppice
6	Horticulture
7	Vineyards
8	Garrigue
9	Bush, macchia
10	Moor
11	Halophile grassland
12	Arboriculture, orchard
13	Industrial crops
14	Rice
15	Cotton
16	Vegetables
17	Olive-trees
18	Recreation
19	Extensive pasture, grazing, rough pasture
20	Dehesa (extensive agricultural-pasture system in forest parks in Spain)
21	Cultivos enarenados (artificial soils for orchards in SE Spain)
22	Wildlife, above timberline

Texture class: Surface soil

TEXT1	Dominant surface textural class.
TEXT2	Secondary surface textural class.
(Present in:	*STU)*
0	No information
9	No texture (histosols, ...)
1	Coarse (clay ≤ 18 % and sand > 65 %)
2	Medium (18% ≤ clay < 35% and sand > 15%, or clay ≤ 18% and 15% ≤ sand < 65%)
3	Medium fine (clay < 35 % and sand < 15 %)
4	Fine (35 % ≤ clay < 60 %)
5	Very fine (clay ≥ 60 %)

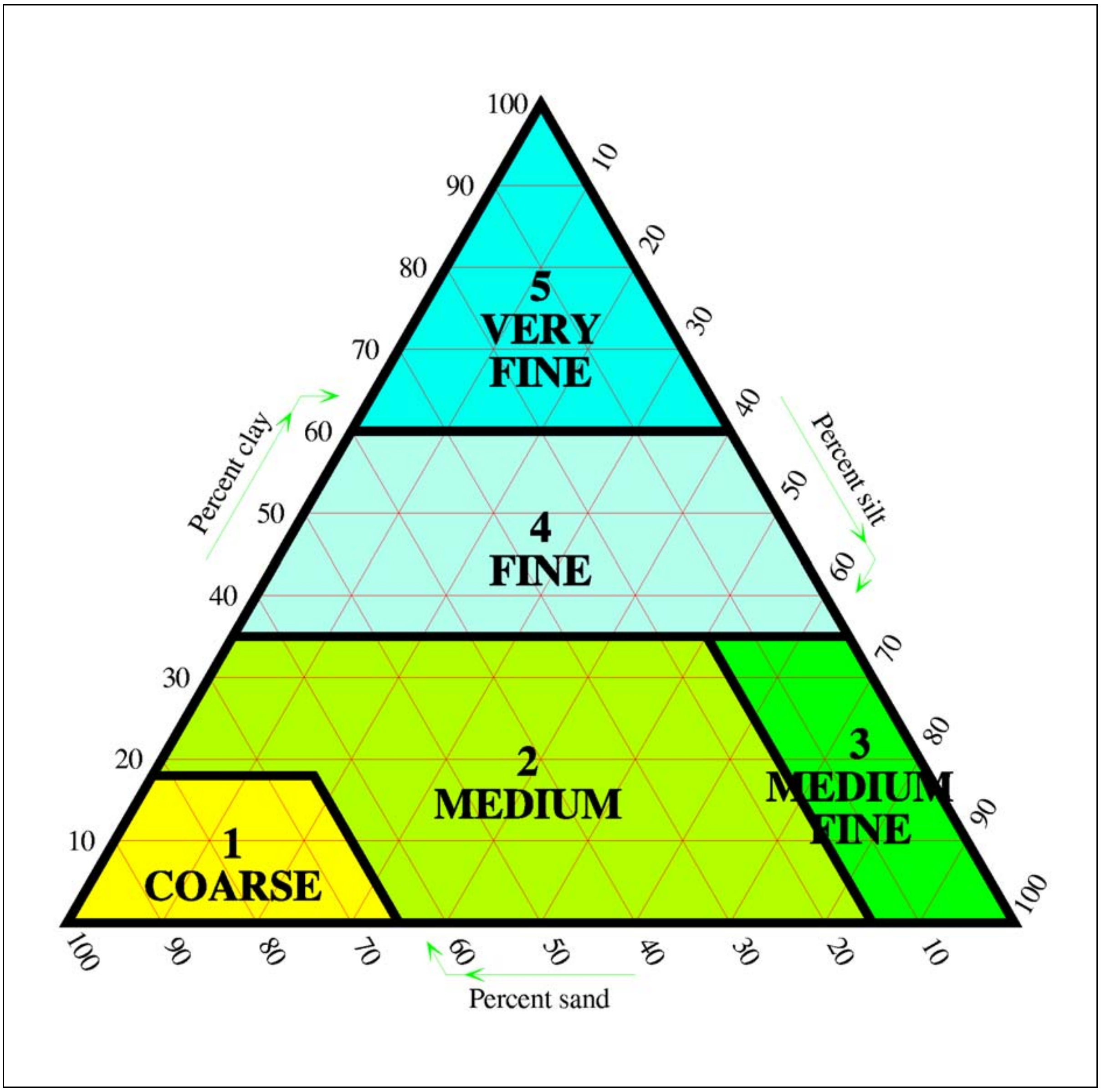

Figure 18. Particle-size classes of FAO

Water Management

WM1	Normal presence of a water management system in agricultural land (on > 50% STU).
(Present in:	*STU)*
0	No information
1	Yes, agricultural land normally has a water management system
2	No, agricultural land normally has no water management system

Water Management: Purpose

WM2	Purpose of the water management system.
(Present in:	*STU)*
0	No information
1	To alleviate waterlogging (drainage)
2	To alleviate drought stress (irrigation)
3	To alleviate salinity (drainage)
4	To alleviate both waterlogging and drought stress
5	To alleviate both waterlogging and salinity

Water Management: Type

WM3	Evident type of water management system.
(Present in:	*STU)*
0	No information
1	Pumping
2	Ditches
3	Pipe underdrainage (network of drain pipes)
4	Mole drainage
5	Deep loosening (subsoiling)
6	'Bed' system (ridge-furrow or steching)
7	Flood irrigation (system of irrigation by controlled flooding as for rice)
8	Overhead sprinkler (system of irrigation by sprinkling)
9	Trickle irrigation

Water Regime

WR	Dominant annual average soil water regime class of the soil profile.
(Present in:	*STU)*
0	No information
1	Not wet* within 80 cm for over 3 months, nor wet within 40 cm for over 1 month
2	Wet within 80 cm for 3 to 6 months, but not wet within 40 cm for over 1 month
3	Wet within 80 cm for over 6 months, but not wet within 40 cm for over 11 months
4	Wet within 40 cm depth for over 11 months

* Wet = waterlogged; defined as: a matric suction of < 10 cm, or a matric potential of > -1 kPa.

EUROPEAN SOIL BUREAU RESEARCH REPORTS

No.1 European Land Information Systems for Agro-environmental Monitoring. D. King, R.J.A. Jones and A.J. Thomasson (eds). EUR 16232 EN, 284pp. (1995). Office for the Official Publications of the European Communities, Luxembourg.

No.2 Soil Databases to support sustainable development. C. Le Bas and M. Jamagne (eds). EUR 16371 EN, 149pp. (1996). Office for Official Publications of the European Communities, Luxembourg.

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No.4 Land Information Systems: Developments for planning the sustainable use of land resources. H.J. Heineke, W. Eckelmann, A.J. Thomasson, R.J.A. Jones, L. Montanarella and B. Buckley (eds). EUR 17729 EN, 546pp. (1998). Office for Official Publications of the European Communities, Luxembourg.

No.5 Georeferenced Soil Database for Europe: Manual of Procedures Version 1.0. European Soil Bureau, Scientific Committee. EUR 18092 EN, 184pp. (1998). Office for Official Publications of the European Communities, Luxembourg.

No.6 Soil Resources of Europe. P. Bullock, R.J.A. Jones and L. Montanarella (eds). EUR 18991 EN, 202pp. (1999). Office for Official Publications of the European Communities, Luxembourg.

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No.8 Soil Geographical Database for Eurasia & The Mediterranean: Instructions Guide for Elaboration at scale 1:1,000,000. Version 4.0. J.J. Lambert, J. Daroussin, M. Eimberck, C. Le Bas, M. Jamagne, D. King & L. Montanarella. EUR 20422 EN, 64pp. (2003). Office for Official Publications of the European Communities, Luxembourg.

No.9 Soil Resources of Europe: Second Edition. R.J.A. Jones, B. Houskova, P. Bullock and L. Montanarella (eds). EUR 20559 EN, 420pp. (2005). Office for Official Publications of the European Communities, Luxembourg.

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No.14 Field Guide to the Soil-landscapes of the Piemonte eastern plain. F. Petrella, M. Piazzi, P. Martalò, P. Roberto, F. Giannetti, N. Alliani, V. Ancarani, G. Nicoli, R. Salandin, & N. Filippi. EUR 20829 EN, 33pp. (2003). Office for Official Publications of the European Communities, Luxembourg.

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No.16 Pan-European Soil Erosion Risk Assessment: The PESERA Map, Version 1 October 2003. Explanation of Special Publication Ispra 2004 No.73 (S.P.I.04.73). M.J. Kirkby, R.J.A. Jones, B., Irvine, A. Gobin, G. Govers, O. Cerdan, A.J.J. Van Rompaey, Y. Le Bissonnais, J. Daroussin, D. King, L. Montanarella, M. Grimm, V. Vieillefont, J. Puigdefabregas, M. Boer, C. Kosmas, N. Yassoglou, M. Tsara, S. Mantel, G.J. Van Lynden and J Huting. EUR 21176 EN, 20pp. and 1 map in ISO B1 format. (2004). Office for Official Publications of the European Communities, Luxembourg.

No.17 The map of organic carbon in topsoils in Europe, Version 1.2 September 2003: Explanation of Special Publication Ispra 2004 No.72 (S.P.I.04.72). R.J.A. Jones, R. Hiederer, E. Rusco, P.J. Loveland, and L. Montanarella. EUR 21209 EN, 26pp. and 1 map in ISO B1 format. (2004). Office for Official Publications of the European Communities, Luxembourg.

No.18 Computer program on DRIS, MDRIS and CND - bivariate and multivariate analyses tools for monitoring the soil and plant nutrient imbalances. Senthil-Kumar Selvaradjou, Luca Montanarella & Aruna-Geetha. EUR 21505 EN, 49pp. (2005). Office for Official Publications of the European Communities, Luxembourg.

No.19 SPADE-2: The Soil Profile Analytical Database for Europe, Version 1.0. John M. Hollis, Robert J.A. Jones, Charles. J. Marshall, Ann Holden, Jan Renger Van de Veen & Luca Montanarella. EUR 22127 EN, 38pp. (2006). Office for Official Publications of the European Communities, Luxembourg.

No.20 European Soil Database: soil property data in 1km raster format. R. Hiederer, R.J.A. Jones, and L. Montanarella. EUR 21nnn EN, ??pp. (2006). Office for Official Publications of the European Communities, Luxembourg. [In Preparation].

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